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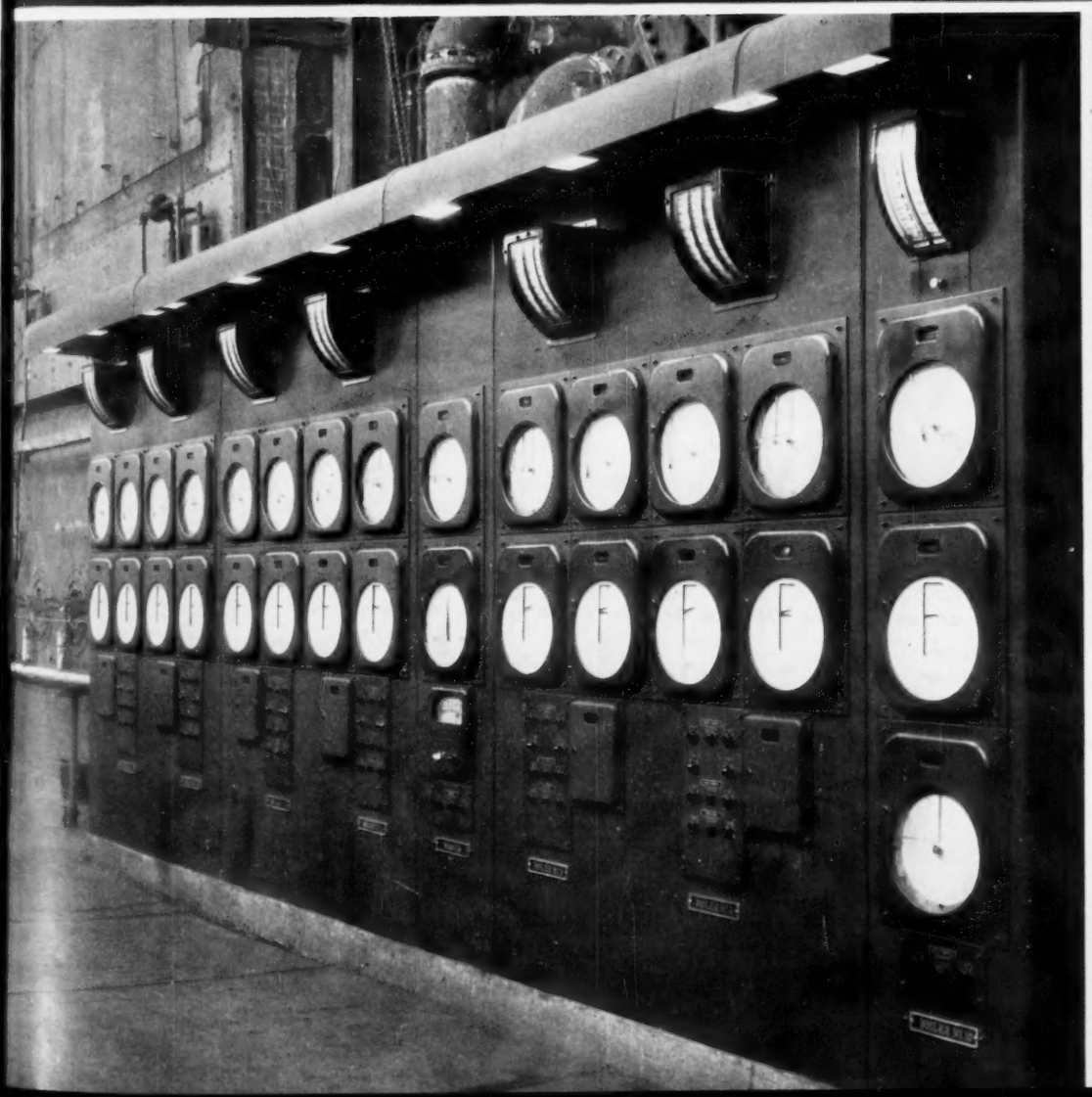
INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT and CONTROL



VOLUME 10

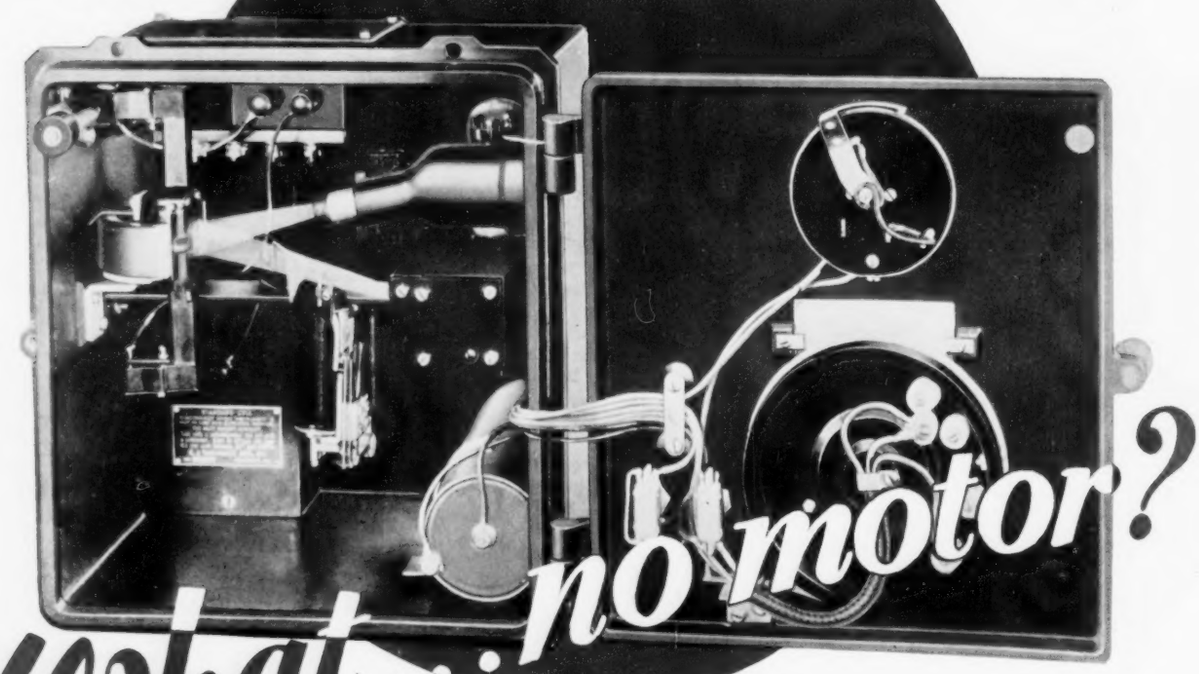
MARCH

1937

NUMBER 3

TAG CELECTRAY

Here's the most Sensitive INDICATING CONTROLLER



What . . . no motor?

No! but it does have *Instantaneous* photo-electric detection

COMPLETE LINE OF PYROMETERS AND PRESSURE SPRING INSTRUMENTS

LEVEL

FLOW

PRESSURE

TEMPERATURE

This TAG CELECTRAY gives new life to "on-off" 2-position and 3-position control! Unhampered by a chopper bar and galvanometer boom, and therefore controlling every instant, instead of through momentary contacts once in a while, its split-second action restricts overswing to the ultimate minimum.

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The TAG CELECTRAY is the ideal controller, not only for many industrial uses, but for a wide variety of laboratory purposes as well. Do you want to control to 0.1° — .01° — one microvolt? . . . Ask us about this, and send for the TAG Pyrometer Catalog No. 1101B-1 today.

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C. J. TAGLIABUE MFG. CO.
Park and Nostrand Aves., Brooklyn, N. Y.

Gentlemen: Please send me a copy of the TAG Pyrometer Catalog No. 1101B-1

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Address .....

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Measure Minute Currents without leveling

WESTON *double pivoted*

MICROAMMETERS

MILLIVOLTMETERS

Gone is all need for leveling the instrument when measuring minute currents. The WESTON Model 622 series of ultra-sensitive instruments—being of the double-pivoted type—are used simply in the normal horizontal position, without leveling. The instruments in this series include DC and AC Thermocouple types, and are available in ranges and sensitivities for ordinary field and laboratory work, as well as for service demanding ultra-sensitivity; such as circuits involving thermocouples, pyrometers, electron tubes, etc. The cases are Bakelite, of modern design; and the large scale opening and increased length of the hand-calibrated mirror scale simplifies accurate reading. The instruments in ranges from 20 microamperes up are electrostatically and magnetically shielded. Lower ranges, down to 5 microamperes, are electrostatically shielded.

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One of the most complete catalogs on one class of instruments ever produced. Follow arrow to coupon for your copy . . . . .

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60-Page Taylor Catalog shows the very latest in Rate-of-Flow and Liquid Level Instruments, covering—

INDICATING—INTEGRATING—RECORDING—CONTROLLING TYPES FOR ALL CLASSES OF SERVICE

1-, 2-, and 3-pen Flow Recorder for differential pressure, static pressure or temperature.

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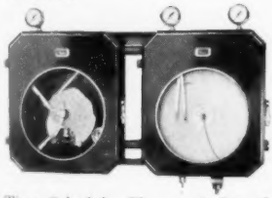
Static-pressure Liquid Level Recorder.



Time-Schedule Flow and Liquid Level Controller.

Send COUPON for this FREE Comprehensive Review of Taylor Developments

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Taylor Flow and Liquid Level instruments are the result of a well-rounded program of intensive research and development. In actual service, they have proved that the same confidence can be placed in them as in other Taylor products.

The primary devices are time-proven in principle and practice, and conform with the latest findings of the leading technical organizations. The secondary or measuring devices are standard Taylor Instruments—renowned throughout industry for their accuracy and long-lived dependability. The many standard and special-purpose instruments are treated in such a manner as to make selection for a specific job extremely simple.

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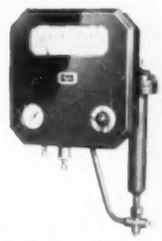
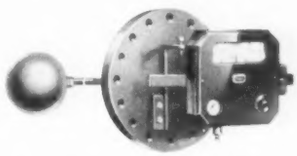
Remember this fact, too: Taylor Engineers have the technical training and wide experience in industrial processing to analyze your flow and liquid level problems, prescribe the required instruments and, if desired, supervise their installation. They are also often able to make other recommendations which will produce a more efficient and highly coordinated system of processing throughout your plant.

Ask a Taylor Representative for this service. But first of all get this new Catalog 70 J. The easiest and quickest way is to send the coupon.



Indicating Flow and Liquid Level Controller.

Recording Flow and Liquid Level Controller.



Internal-float Liquid Level Controller.

External-float Liquid Level Controller.

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Rochester, N. Y. (Toronto, Canada—if you are in Canada)

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Please send me by return mail your Catalog 70 J on Flow and Liquid Level Instruments.

Name_____

Position_____

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

A few readers have suggested that we occasionally print articles on the "pure science" foundations of various branches of Instrumentation. We are reluctant to print anything not "practical" but we'd have printed Dr. Williams' instalment even if it were not part of his serial, for here at least is an account of atomic structure which all readers interested in hardness will find directly useful in clarifying their ideas.

Directly useful, too, is Ralph Batcher's article on cathode-ray tube applications in the automotive field. And more coming next month!

This month's instalment of our Manual of Instrumentation is not only directly useful but intensely practical. It is contributed by Ed S. Smith, Jr., already known to our readers for his valuable previous contributions,* and further known to A.S.M.E. members as one of that great Society's most brilliant contributors of papers and discussions. He ably discusses the hydraulic side of fitting a control valve to an application of automatic control. He shows that while such a valve generally follows the physical laws of flow meters, it nevertheless constitutes only one resistance in a line containing several resistances. The examples he selects are not so much typical as limiting cases.

*Including that noteworthy contribution of his as co-author of the March 1933 instalment (Chapter XXVIII) on automatic control of fluid flow. In this, he classified and analyzed flow-rate controllers so brilliantly that this work of his deserves to be recognized as a milestone in the progress of automatic-control technology.

THE FRONT COVER

shows the control panel at the Bigelow Sanford Carpet Co., Thompsonville, Conn., and the Hays Corp. describes it as follows: Top row, six 3-pointer draft gages and one 2-pointer draft gage. Second row, left to right, one Hays combustion meter, two Cochrane steam flow meters, two Hays combustion meters, two Cochrane steam flow meters, one Hays combustion meter, one Cochrane steam pressure recorder, one combustion meter, two Cochrane steam flow meters, one combustion meter, one Cochrane steam flow meter. Third row, fuel feed and air flow control units with a master control in center. Bottom row, furnace draft controllers and push button stations for individual boilers, with signal lights immediately below some, also forced-draft duct indicator, Hays Combustion meters and push-button station.

CONTROL TERMS

IN his January article, Dr. Williams, referring to that ill-defined property known as "hardness," quoted from Plato's *Republic:* "Any name will do which expresses the thought of the mind with clearness."

Would that this were the case—you no doubt think—with the terms employed in automatic-control technology! So thinks your editor. For twelve long years he has been trying to bring a little law-and-order into it. His first successes came when he became associated with *Instruments* and used its columns. In 1930, '31 and '32, thanks to the support of The Instruments Publishing Company, thanks to the cooperation of manufacturers' engineers, and thanks above all to the fact that the readers of *Instruments* are the ones who have the final say-so, he received tacit pledges of conformity from the most important organizations concerned. Some made reservations, but it was the first definite forward step. The "approved" basic terms were published.*

The subsequent detailed job being too big for one man, it was decided by the leaders of the movement to throw it wide open to volunteer helpers from all quarters, and as a result of this joint decision the following editorial was published in the August 1934 issue of *Instruments:*

One of the things we like to do is to discuss instruments with instrument men. So do you. And we bet the kind of powwow that doesn't break up until past midnight is the one where you and your brother instrumenticians discuss automatic controllers, where quires of paper get filled with control system hook-ups and formulas, and where friendly but impassioned arguments rage . . .

Haven't you noticed that whenever a newcomer makes his appearance in your circle—from another branch of instrument work, from another profession or from another company—you have a hard time understanding him, and he you?

It's nobody's fault—and everybody's: in the field of automatic control technology several languages, all made up of English words, are being used. You can verify this by comparing articles on control technology in different journals, or by listening to the sales engineers from different companies who call on you, or by attending a meeting where several papers are read, dealing in whole or in part with control.

Here are some of the terms that undergo changes of meaning . . .

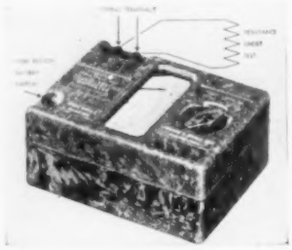
Back of it all is the fact that automatic control practice is so far ahead of theory that throughout all these years of ingenious developments the principal terms and basic general principles of "instrument control" technology had not been formulated, and never appeared in print until two years ago. And this text* is only a meager beginning.

There seems to be a need for something to be done about it. No group of men is better qualified than are the readers of *Instruments.*

Since then, much progress has been made, but we are not yet authorized to publish the further results. We are instructed, however, to remind our readers that the invitation still stands. Send *your* ideas to this office: the clearing-house.

*Fundamentals of Instrumentation, 1932.

MIDGET "MEGGER"
CIRCUIT TESTING
OHMMETER



Independent of Battery Voltage
Ranges—from .1 ohm up to 200,000 ohms

Quite different from a voltmeter calibrated in ohms, this direct-indicating "Megger" Ohmmeter requires no adjustment for the voltage of the battery that supplies current for the test. The instrument is a true ohmmeter of the "Megger" cross-coil type having great flexibility as to range and is remarkably accurate and reliable. Well adapted for laboratory, shop and portable use for checking coils, resistors, contacts, windings, circuits, relays, etc., and even insulation resistance up to 200,000 ohms. Mounted in molded case, mottled green in color. *Write for descriptive Bulletin 1380-I.*

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ELECTRICAL INSTRUMENTS
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Controlling Temperature of
OVENS WATER BATHS
LABORATORY INCUBATORS
where extreme accuracy is essential

The New "HS-4"

This is an ultra-sensitive, yet rugged temperature controller designed especially for ranges with upper limit of 150°C. or 300°F. Its adjustable range is 75°C. or 150°F., depending upon the active length of tube. *Operating differential 0.1°C.* Even under most difficult conditions a differential of 0.2°C. is obtained.

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Hard Burloid contacts. Uniform performance. Operates in air or liquids. No glass to break or mercury to spill.

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NEW INSTRUMENTS

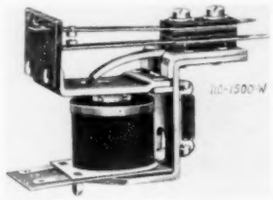
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Small Relays

Two new relays are announced: "Series 110" a.c. and "Series 115" d.c. The former, of which illustration shows simplest unmounted style, is available in contact combinations ranging from single-pole single-throw to four-pole double-throw. Full-floating armature is said to eliminate friction, binding and sticking. Hum and chatter are prevented by the use of a relatively large shading ring



attached firmly to core of coil. Relay will not heat, even when in continuous circuit, when operated within prescribed voltage (any up to 220). Current draw approx. 2 watts. Other features are adjustable air gap unaffected by vibration, silver contact points riveted to phosphor-bronze springs and adjusted for self-wiping, Bakelite lifter bar, cadmium-plating, etc. "Series 115" has most of these features, draws 3 watts at 110 volts, can be supplied with contacts with capacities up to 1500 watts non-inductive load at 110 volts 60-cycle.—*Guardian Elec. Mfg. Co., 1621 Walnut St., Chicago, Ill.*

Mercury Rectifier

New "Type 2-RA-6," interchangeable with other bulbs of the same rating, differs from conventional charger bulb design. A new non-sagging type of filament has been designed along the lines of those used in industrial tubes: manufacturer guarantees the 2-RA-6 for 2000 hours. Another feature is the universal cap connection: permits use of Fahnstock clip or any other type that may be convenient, also guards against breakage of the glass seal in event that anode lead should be struck. Filament current consumption and the voltage drop, or wasted power, is said to be unusually low. Base connection is welded to guard against possible burn-outs in event of a faulty contact. Electrical characteristics: Filament volts, 2; Filament amps., 13; Output amps., 6; Inverse peak voltage, 300.—*Continental Electric Co., Geneva, Ill.*

Small Air-operated Temperature and Pressure Controllers

A new non-indicating controller known as the Wide Range Controller, Type 2426, is housed in a 4½" Phenol case, operates on air pressure of 15 lbs./in.², and has a throttling range of 1% to 15%. Temperature type has a graduated range of —30 to 500°F.; pressure type has a graduated range of 15 to 500 lbs./in.². Where required, the temperature controllers are supplied with vapor tension bulbs with selection of fittings, con-

nections and separable sockets to fit application and, where required, with "balanced capillary tubing" to compensate for room temperature variations.—*American Schaeffer & Budenberg Div. of Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.*

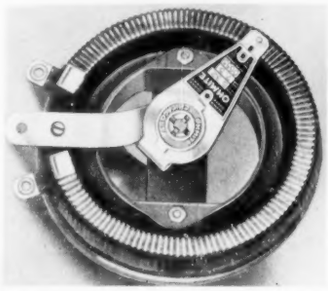
Electric Counters

A new line of electric counters, with five digits in either the reset or non-reset types, has been made available. Their construction is such that the load on the operating mechanism is constant regardless of what number is being

counted. This is accomplished by gearing the indicating wheels together, as is done in a watthour meter. Duty on operating mechanism is practically the same as on a relay. Load remains constant whether 1 or 10,000 is being counted. This eliminates tendency to skip when only one or two wheels should be turning and miss when all of the wheels should be turning. Only one number appears at a time.—*Struthers Dunn, Inc., 125 N. Juniper St., Philadelphia, Pa.*

One-kilowatt Rheostat

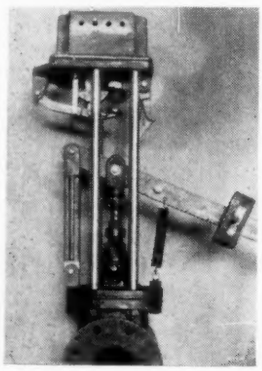
New power rheostat, known as [illegible] U," rated at 1000 watts, 12" in [illegible]eter, is said to be capable of con[illegible]ing many types of loads formerly [illegible]ed to require the button contact [illegible] and rheostat. Constructed of metal [illegible] ceramic materials throughout, nothing can smoke or char. Resistance wire is wound over a horseshoe-shaped porcelain core mounted on a porcelain base. Entire unit, except contact surface, is then covered with vitreous enamel and fired at a high temperature. Upon cooling, enamel hardens, holds each turn of wire rigidly in place, and fuses entire assembly into one integral unit. Shaft and bushing assembly is insulated from



live circuit by porcelain. Uniform contact is made on flat contact surface of windings by means of a spring-held contact arm fitted with a universal-joint action metal-graphite contact shoe which spans several resistance steps at all times, thus making pressure on any one step negligible.—*Ohmite Mfg. Co., 4835 W. Flournoy St., Chicago, Ill.*

Solenoid Trip Gate Valve

This new solenoid trip gate valve is primarily intended for use as an emergency stand-by valve. Under normal conditions it will remain as manually set,



but in event of an emergency (which may be reacted back to valve either from loss of current or from application of current) the solenoid will act, release the valve arm and allow valve to close. Among the applica'ions are the following: (1) Valve inst lled in discharge of motor-driven gas blower, with solenoid connected across motor terminals, so that in case of loss of current to motor, valve would close and prevent back flow of gas. (2) Installed in steam, gas or other pressure line with push buttons installed at remote points.—*Ruggles Klingemann Mfg. Co., Salem, Mass.*

Three-inch Size Panel Type Electrical Instruments

A new line of 3" square-case flush- or surface-mounting a-c. and d-c. instruments includes ammeters, milliammeters, microammeters, voltmeters and dynamo-

meter wattweters. D-c. instruments are of the permanent-magnet moving-coil type. Magnet is a removable forging of chromium alloy steel or of cobalt, tipped with accurately machined soft iron pole pieces; and core is ground to size and fits in exact center of air gap. Entire moving system has a high overload factor. Moving-vane and electrodynamometer movements of a-c. instruments are of rugged construction and power consumption is low. Vanes are made from a magnetic material said to have negligible hysteresis loss.—*The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

Glass Electrode pH Meters

New line of pH Electrometers, for measuring pH with the glass electrode in factory or laboratory, includes seven instrument combinations and a variety of electrode assemblies which specifically adapt the equipment to each of a variety of industrial applications. "Model 3" instruments are portable, self contained and intended for field and factory as well as laboratory service, being sufficiently rugged to withstand rough usage. Modifications allow direct readings both of pH and millivolts while a special Redox electrode is supplied with such instruments for oxidation-reduction determinations. Automatic temperature compensation. Factory-sealed electrodes require no attention from the operator, are small and safely housed in annular protecting rings. "Model 3" is electrically accurate to 0.1%, sensitive to 0.2 mv. and chemically accurate to 0.05 pH. The range is 0-13 pH, 0-1300 mv. and 0-50°C. "Model 4" instruments are for laboratory use, powered from 110-volt 60-cycle supply through a voltage compensating power pack separately mounted and connected to the instrument through a 10-ft. cable. All modifications are calibrated 0-1630 mv. by 1 mv. divisions and are easily read to 0.2 mv. A direct reading pH scale and also an automatic temperature compensator for pH are optional. Electrical accuracy is 0.1% sensitivity 0.1 mv. Internal resistance of 10^{14} ohms renders this model particularly adaptable to high resistance measurements and other low-energy applications. Either model may be used as a ballistic galvanometer.—*Coleman Electric Co., Inc., 300 Madison St., Maywood, Ill.*

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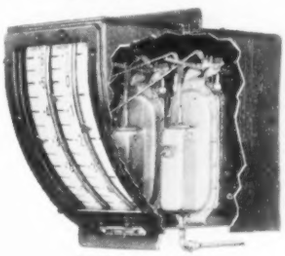
METERS and CONTROL *for Boiler Room Service . . .*

Boiler Meters Indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature. The use of this meter reduces fuel cost, lessens maintenance and outage, lowers standby costs, and adds capacity.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems. Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

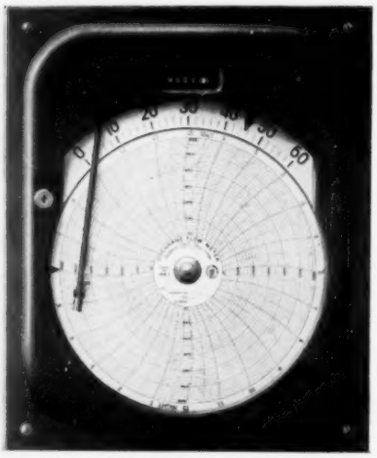
Complete Information on any of the above Bailey products will be gladly furnished upon request. G-7

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

COCHRANE
FLOWMETERS

Accurate — Sensitive — Rugged



Adaptable to industrial service wherever the flow of steam, water or other liquids or gases is involved. Cochrane Flow Meters are sturdily built and extremely sensitive to variations in flow.

Recorders of both the Electric and the Mechanical models are guaranteed accurate within one-half of one per cent of absolute under full load.

Cochrane Electric Flow Meters operate on the super-accurate galvanometer null principle. They may be installed at any distance from the pipe line, facilitating central panel grouping.

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Let the TRU-VAC gauge tell you—accurately—continuously. Records pressures from 0—10,000 microns. Invaluable in processes requiring dependable knowledge of vacuum conditions.

Its numerous advantages are outlined in our bulletin TV2, gladly sent upon request.

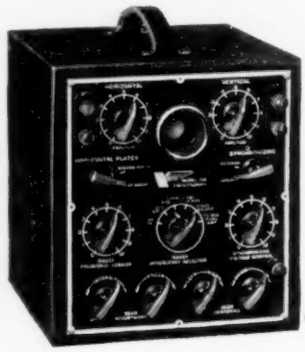
CONTINENTAL ELECTRIC CO.

Geneva, Illinois

PHOTOCELLS VACUUM SWITCHES

Midget Cathode-Ray Oscillograph

Recent development of the Type 913 cathode-ray tube with a one-inch screen and greatly reduced voltage requirements has made possible the design of an extremely compact cathode-ray oscillograph. New "Model 105" is said to offer every electrical and testing feature of larger instruments, yet measures only 9" x 9" x 9½" and weighs 16 lbs. This instrument is complete with a Thyratron-



controlled self-synchronizing linear timing axis generator, input amplifiers for both horizontal and vertical plates, and power supply for operation from line voltages. Facilities are provided for study of voltage and current waves, power factor, relay operation and timing, transient surges, etc. "Model 105" may be described in brief as a smaller replica of maker's Model CRA (see *Instruments*, March, 1936, page 60; April, 1936, page 112).—*Clough-Brengle Co., 2813-F West 19th St., Chicago, Ill.*

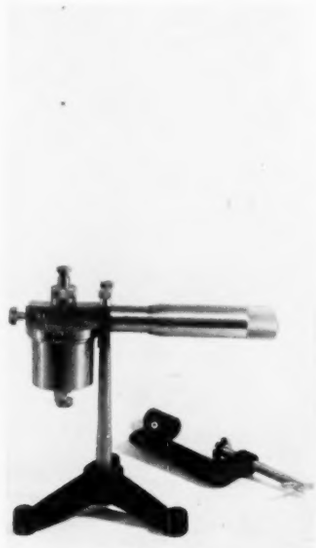
Signal Generator

Claim for new "Model 120A" direct-reading 115-volt 50-60 cycle a-c. operated signal generator is that it will attenuate a signal to absolute zero without r-f. leakage, thus permitting accurate sensitivity measurements. Maximum output signal strength has been increased to

200,000 μv. for afc. service work. Frequency range is from 100 kc. to 27 Mc. on fundamentals and to 75 Mc. calibrated dial. R-f. signal may be modulated at 30% with a 400-cycle audio tone supplied through a separate tube in a suppressor injection circuit. Audio tone may be used alone or external modulation may be supplied to the generator. Calibrated microvolt attenuation from approx. 1 μv. to 50,000 μv. is accomplished with a dual attenuator system. New generator employs a 6C6 r-f. oscillator, a 76 suppressor injection audio modulator and a 76 rectifier tube. Black crackle finished terne plate metal case 6¼" x 9" x 5½" deep.—*Triumph Mfg. Co., 4017 W. Lake St., Chicago, Ill.*

Core Porometer

This new instrument is for determining the porosity of consolidated core samples. Principle depends on compressibility of air in pore space of sample. In-



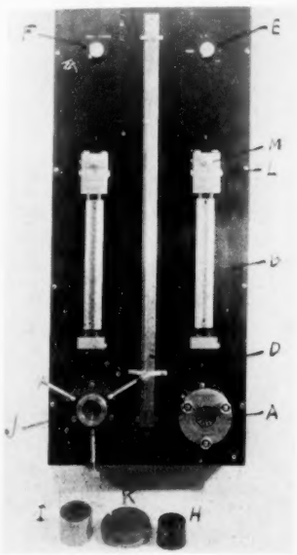
strument consists of an air-tight cup to which is attached a piston for measuring displacement volumes by measuring piston travel. Height in a capillary tube is used to determine reference pressures. In use, the bulk of the core, after having been extracted and dried properly, is first determined by mercury displacement in the cup. For this purpose, the cup with a small perforated lid serves as a pycnometer. The overflow mercury corresponds to the bulk volume of the core. To determine available pore space, core sample is placed in container and the air compressed by the metering piston until mercury in the capillary tube reaches reference mark. Reading on sleeve of metering piston indicates summation of volumes of the sand grains. A core sample is not damaged by running a porosity test with this device. The same core sample may be used for other determinations or, in case of doubtful results, check runs may be made with same sample. Instrument and all accessories are contained in a mahogany case 9" x 6" x 4", total weight 6½ lbs.—*Waller Rusko & Co., Inc., Houston, Texas.*

Universal Condenser Replacements

Three universal replacement condensers permit many capacity combinations without loss of time, are small enough to "fit in anywhere" and are adaptable to any type of mounting. "Type BT-100" is a rectangular unit having three 8-mfd. sections (8-8-8 mfd. 200 volts) and two 5-mfd. sections at 25 volts. From the individual sections and leads, combinations such as 8-16 mfd.; 12-16; 10-16; 5-25, etc. may be obtained, also, the 5 mfd. sections may be combined as a single 10 mfd. unit. This same unit in a round cardboard casing with mounting lugs is known as "Type ST-10." The third, "Type BT-1," has three 150-volt sections 5-10-25 mfds. Six leads give any needed combination of these capacities.—*Sprague Products Co., North Adams, Mass.*

Core Permeameter

A new instrument is designed to measure the permeability of consolidated [illegible] sections. Air of known temperature and pressure is forced through a core



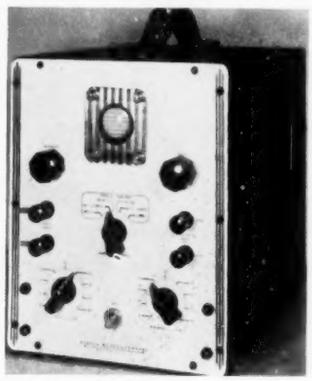
sample of known cross-section and thickness. The flow of the air through the sample is determined with a flowmeter. Instrument consists of core holder A, flowmeter B (with thermometer) and manometer D with the necessary control valves E and F. Illustration shows a double unit with two core holders and flowmeters, which can be used separately or together. Core sample first has all its oil extracted, then is mounted in tapered rubber stopper H which fits snugly into machined holder I (which has same taper as rubber stopper). By means of mount J and perforated plate K, core is clamped air-tight in holder. A short 8-mm. nipple projecting from mount J serves as inlet connection for the air as it enters from flowmeter B. The perforations in this plate (see A) allow air as it passes through core sample to exhaust at atmospheric pressure. Flowmeter B uses differential principle, "metering plate" being inserted in a side opening and held in place by sealing plug L. Stop-cock M controls air flow, enables operator to prevent blow-over.—*Walter Ruska & Co., Inc., Houston, Texas.*

Black & White Cathode-ray Tube Screen Material

By reason of increasing demand on the part of experimenters, and bright prospects of commercial television in near future, there has been developed a screen material for cathode-ray tubes which allows a black-and-white effect. Intensity of spot is approx. same as blue or green but is obviously more satisfactory. New black-and-white screens may now be obtained on the DuMont 3", 5" or 9" cathode-ray tubes, Types 34-XII, 54-8-H or 94-8-H respectively. Tests have been made on these various tubes for television reception and necessary modifications have been made in them so that they can be used equally well in a cathode-ray oscillograph or television receiving set.—*Allen B. DuMont Labs., Inc., Upper Montclair, N. J.*

Cathode-ray Oscillograph

"Model 60 Oscilliscope" is a self-contained ready-to-use unit powered directly from 110-volt 60-cycle supply. A vertical amplifier increases the vertical deflection sensitivity throughout the audio- and lower radio-frequency spectrum. No horizontal amplifier is provided within the instrument, horizontal deflection sensitivity being controlled by that of the cathode-ray tube itself. An a-c. sweep of the line power frequency



supplies a horizontal time axis at that frequency. For other timing frequencies an external timing voltage may be connected to the horizontal input posts. Both the horizontal and vertical input circuits are provided with gain controls which control the deflection sensitivity regardless of the position of the "Horizontal Input" selector switch. D-c. voltages may be measured on the vertical or horizontal plates. Cathode-ray tube is new 1" No. 913, is provided with a cross-section transparent screen calibrated in arbitrary units. Power consumption, 30 watts; Fuse protection, 0.75 amps. Max. vertical input sensitivity per inch: amplifier on, 1 volt a.c. r.m.s., amplifier off, 75 volts a.c. r.m.s. amplifier off, 200 volts d.c.; Max. horizontal input sensitivity per inch: 75 volts a.c. r.m.s or 200 volts d.c., Input impedance to either horizontal or vertical input posts, 1 megohm. Maximum signal to input posts, 400 volts d.c. or 300 volts a.c.—*Burton Rogers Co., 755 Boylston St., Boston, Mass.*

Thermometric Paints

Several of the chemical compounds whose change of color at certain temperatures has heretofore been little more than a scientific curiosity have now been made use of in a practical way as ingredients in a commercially available line of paints, all easily applied by brush, all drying in about 24 hrs., and all available in 1-, 2-, 4- and 8-oz. and 1-lb. jars. There are two series: "Retroactive" paints which change back to original color when cooled; and "Permanent" paints which display an irreversible reaction. Some examples:

Serial No.	*Trans. Point*	*"Cold" color*	*"Hot" color*	*Change back*
1	85°C.	Red	Black	Yes
2	40°C.	Yellow	Orange	Yes
3	50°C.	Green	Brown	Yes
8	140°C.	Red	Yellow	No
11	310°C.	Light red	Black	No
12	390°C.	Scarlet	Black	No

—*The Efkalin Co., 804 E. 141st St., New York City.*

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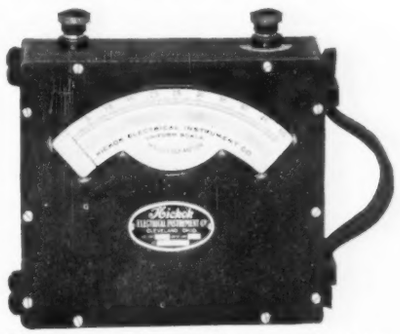
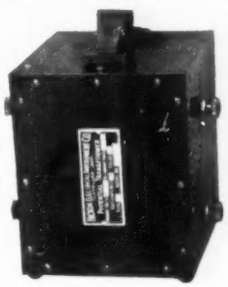


Made open face, or with hinged, closing covers. Illustrated above is Model 18, accuracy 1/2%.



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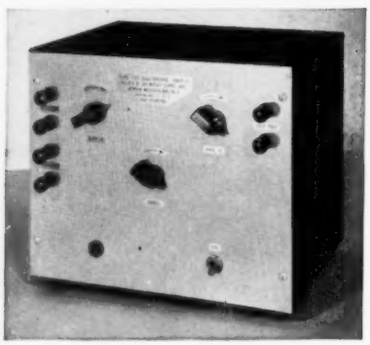


This instrument when used in conjunction with a Cathode Ray Oscillograph vastly increases the value of the Oscillograph.

It allows: Simultaneous observation of any two voltages or current phenomena-inspection and comparison of wave form or phase of two voltages or currents from different parts of the same circuit—comparison of wave form of a standard wave with another wave—it can be applied to a timing wave in conjunction with the wave under observation.

Unit is self-contained and operates from 110-120 volt, 60 cycle circuit. Controls are provided for adjusting gain of amplifiers and for varying the speed of switching.

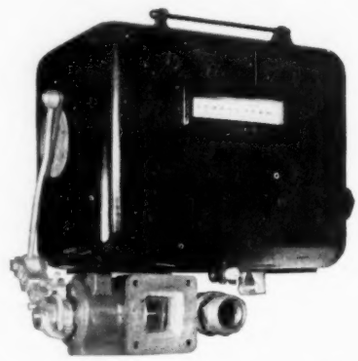
Frequency Range 10-500,000 c.p.s. Gain of Amplifier in Audio Frequencies—40. Power consumption—50 watts.

Write for complete catalogue of Du Mont Cathode Ray Tubes, Oscillographs and accessory apparatus.

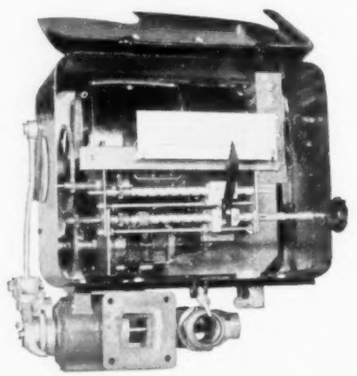
ALLEN B. DU MONT Laboratories, Inc.
532 Valley Road Upper Montclair, N. J.

Temperature Control Unit

"Lindberg Throttling Control" is described as a "new type" of unit which is to be used in connection with a control instrument and which "operates on a new principle . . . definitely eliminates all possibility of drifting above or below the control temperature . . . a distinct advance over former types of throttling controls which operated on the basis of varying the valve opening in relation to the deviation from control temperature." Unit consists of a proportioning valve driven by a reversible motor. Low limit switch is fixed while upper ("O") switch is automatically adjusted by means of a small reversing motor, operated by the



contacts on the control instrument. When the temperature is in "neutral" (between "L" and "H"), the valve remains fixed at the point set by the adjusting limit switch. Temperature departure above or below "neutral" zone causes immediate adjustment of valve opening. Extent of



this adjustment is "directly proportional to the time required for the temperature to retrieve normal." If temperature departs from normality zone on the high side, "H" contact closes, shutting off the heat supply entirely and, at the same time, lowering the position of the adjustable limit switch. When temperature returns to normality zone, "H" contact opens; limit switch ceases adjustment, and valve opens to the newly set position. Should temperature tend to drop, limit switch immediately moves to a more open position, extent of adjustment being "in proportion to the time required for recovery." On the assumption that the minimum valve opening to prevent backfiring is 20%, a mechanical stop is placed at this point in the travel of the adjustment switch. Below this point the heating rate is reduced if necessary by the "on and off" mode.—*Lindberg Engineering Co., 221 Union Park Court, Chicago, Ill.*

Portable pH Meters

Combining in one portable outfit all the equipment necessary for making a pH determination by electrometric methods, this new model of the Thwing-Albert pH Meter contains in compartments, electrodes and the vessels and chemicals necessary for their use. Circuit used is potentiometric, no current being drawn

Fig. 1

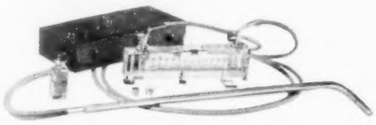
from the electrodes. Readings are directly in pH units on an individually calibrated 4" dial. Scale is readable to 0.02 pH. Galvanometer will stand ordinary bumping around, yet is said to be sensitive to "3 megohms." No standardization or balancing is necessary before reading, indications not being affected by changes in dry cell e.m.f. No change of connections is necessary when voltage relation of electrodes changes from plus to minus, a double-pole double-throw switch being used to make the change. With quinhydrone electrodes (Fig. 2), useful range is 0 to 8 pH; with antimony electrodes (Fig. 3), 2 to 12 pH. Glass electrodes (Fig. 4) cover range 0 to 12.5 pH and are usable in oxidizing and reducing solutions as well as other solutions which would poison the quinhydrone or antimony electrodes. Determinations are unaffected by color or turbidity of solution. Arrangement of elec-

Fig. 2 Fig. 3 Fig. 4

trodes is such that temperature error is ordinarily negligible. New pH meter is available in two models: "Model 1" utilizes a simple potentiometric circuit and is furnished with either quinhydrone or antimony electrodes or with both sets. If, at a later date, it becomes necessary to use glass electrodes also, this model can be converted into the vacuum-tube type. "Model 2" (all-purpose vacuum tube type) utilizes a simple potentiometric circuit with vacuum-tube amplification. Works equally well with quinhydrone, antimony or glass electrodes. Furnished with all three sets if desired.—*Thwing-Albert Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa.*

ir Meters with Pitot-static Heads

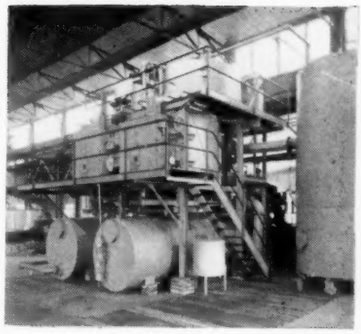
new line of air meters, draft gages, air filter gages is said to incorporate ntages over earlier types, as well as w Pitot-static head for use with the table types. These new instruments provided with quick and easy means leveling. The portable instrument with its rubber tubing and other fittings, luding bottle of spare oil, in case of



portable type, is contained in a carrying case. Various types and ranges are available for velocity ranges as low as 400 ft./min. and as high as 8000 ft./min. or vacuum or pressure ranges as low as 0.005" of water up to 4" of water. A unique feature is the chromium-plated, highly polished scale on the back of the instrument, viewed through the transparent Bakelite body. This polished scale reflects an image of the liquid column, and the reading of the instrument in use, therefore, consists of merely lining up the actual liquid column, the graduated scale (which has a zero adjustment feature), and the reflected image of the liquid column which appears to be beyond the scale. Parallax errors are completely eliminated. The new Pitot-static head, for use either with the new instrument described above or with other instruments designed for similar purposes, is said to be of such a form that it is possible to obtain accurate results even when it is held in such a way that the air stream is coming from a direction as much as 15° from any side of the center line of the head. Since an opening only ½" in diameter is required into ducts, housings, etc., for its insertion, velocity readings are obtained where an anemometer could not be utilized.—*Julien P. Friez & Sons, Inc., Baltimore, Md.*

Gravimetric Liquid Meter

New large type of "Duplex Liquid Scale" was developed especially for weighing oils, gasoline and other flammable liquids as these liquids are delivered between a carrier and storage. Operation is continuous and automatic. Explosion-proof motors and electrical controls. In event of power failure, system can be operated mechanically, without delaying operations. Guaranteed accuracy is ± 0.1%. Assembly consists of two scales mounted on a common frame and electrically and mechanically interlocked with both the inlet and discharge tanks interconnected. Liquid is pumped or delivered to inlet tanks from thense flows by gravity first to one weighing tank and then to the other weighing tank. While one weighing tank receives liquid for its weighing, the other is draining. Upon completion of a weighing in either weigh tank, inlet valve closes and discharge valve opens and weighed liquid flows by gravity to lower discharge-receiving tanks. From these last units the liquid is pumped continuously from the scale or is allowed to flow by gravity. Tanks are never fully emptied, remaining liquid forming a cushion through which flow enters at bottom inlets. All



are connected to a common venting system but in actual operation this system seldom has to open since operation is at atmospheric pressure without fluctuation. In addition to the six main tanks there is a separate emergency overflow tank which connects into the upper tier, provides collecting capacity sufficient to allow time for shutting off the scale supply. The scale illustrated has a weighing capacity of 5,000 kg. in each weigh tank and an hourly capacity of 750 tons. Others, for sugar juice, milk of lime, water, etc., and without the special vapor-confining and explosion-proof features, are built in sizes from 100 lbs. to 3,000 lbs. unit capacities with hourly capacities from 3 tons up to 250 tons.—*Richardson Scale Co., Clifton, N. J.*

Diaphragm-seal Gage

For use on viscous liquids such as paint, lacquer, tar products, plastics, etc., where ordinary Bourdon gage will clog; and for measuring pressure of corrosive fluids or vapors. Also for indicating

liquid level. Combines a Bourdon gage and a diaphragm housing, the whole system being filled with non-freezing and non-compressible liquid. Pressure applied to diaphragm causes liquid to operate Bourdon tube. Diaphragm unit can be opened for cleaning. Available in dial sizes 2" to 16" inclusive, with dial readings from 0-15 lbs./in.² to 0-10,000 lbs./in.²; also for liquid level from 0-30 ft. or higher. On service where instrument is to be subjected to considerable vibration, a heavy-duty movement is incorporated; for service on pulsating pressures, heavy-duty movement and new "Internal Pulsation Dampener" (patent pending).—*Jas. P. Marsh Corp., 2073 Southport Ave., Chicago, Ill.*

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Atomic Structure in relation to Hardness

Third instalment of "Hardness and Hardness Measurements." See page 1, Jan. 1937 issue.

By S. R. WILLIAMS
Professor of Physics, Amherst College

HISTORICAL

When the author began the study of elementary physics forty years ago, he was taught that the atoms which go into the structure of solids, liquids and gases were small elastic particles (something like tiny balls) which were indivisible. In fact the name atom was purposely derived from a Greek word which means indivisible.

The discharge of electricity through gases, radioactivity, spectroscopic evidence, magnetic and electric phenomena—all these contribute now to the point of view that an atom is a complex structure—a structure whose architectural design we are just beginning to appreciate and vaguely understand. The references in the preceding article will form a beginning for those who may be interested in understanding a little of the long story by which we are informed of the present day concepts of atomic structure, which have so important a bearing on our ideas of "hardness."

WHAT IS AN ATOM?

One can answer this question to just that extent to which one's knowledge concerning the atom goes. What is an orange? An accumulation of knowledge concerning the orange is essential for the answer to this question. One could measure its diameter in various directions and obtain an average value, one could obtain its mass and color; and sum up such knowledge by saying that an orange was an orange-colored spheroidal mass of 250 grams and whose average diameter was 8.5 centimeters. Much more, however, could be said about the orange if it were cut open and we examined the contents inside the skin surrounding the juicy segments. When we destroy the orange we learn more about it than by any other method. The same thing is true regarding our knowledge of the atom. The more we have been able to smash the atom into its constituent parts the more have we learned as to how complicated its structure becomes as one progresses from the simplest atom of hydrogen on through the series of 92 elements to arrive at uranium, the most complex of all. Atom-smashing has now become the greatest indoor sport in the world, ranging in its methods from the 85-ton cyclotron of Lawrence and Livingston[1] at the University of California to the huge electrostatic machine of Van de Graaff[2] at the Massachusetts Institute of Technology. The latter is the old "influence" machine set to work on a new problem in which accelerating voltages up to 7,000,000 volts and more have been obtained. In all of these atom-smashing machines there is offered the same quality, in greater or less degree, that by their means one is able to hurl small particles of what we call matter at enormous speeds; and when such a high-speed particle hits an atom a straight head-on blow, something happens: an atom is smashed into some of its constituent parts, whose diameters, masses, and electrical charge values may then be measured.

> The author hereby absolves the editor from all responsibility for the use of the word *negatron* in this article. The word is used as suggested by R. A. Millikan in the quotation printed on the next page.—S.R.W.

These parts of an atom, some of them observed first in the discharge of electricity through gases, others in naturally radioactive bodies and now in the new processes of atom-smashing, have come to be recognized as quite distinct parts of our universe; and atomic structure must in some way account for them.

The quickest way in which to see how these various particles enter into the structure of the atom is to consider the atoms of one element after the other as one proceeds from hydrogen to uranium. In the hydrogen atom

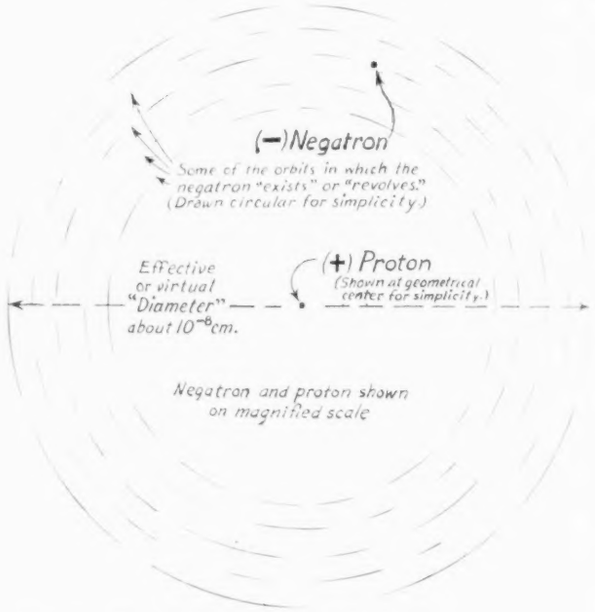
(−) Negatron
Some of the orbits in which the negatron "exists" or "revolves." (Drawn circular for simplicity.)
Effective or virtual "Diameter" about 10⁻⁸ cm.
(+) Proton
(Shown at geometrical center for simplicity.)
Negatron and proton shown on magnified scale

Fig. 20. The constituent parts of the hydrogen atom are one proton, the positive nucleus, and one negatron, the negatively charged particle which determines its chemical properties.

we start from the picture given by Rutherford, that it has two parts, a nucleus and a negatively charged particle attached to the nucleus in some way or other. See Fig. 20. The nucleus of the hydrogen atom is a positively charged particle whose mass is about 1835 times that of the negatively charged particle. Both particles carry the same value of electric charge which Millikan[3] found to equal to $(4.770 \pm 0.005) \times 10^{-10}$ electrostatic unit. More recent observations on this magnitude, with refinements in the method used in measuring the viscosity of air, give the elementary charge a value of $(4.800 \pm 0.004) \times 10^{-10}$ electrostatic unit—which brings the value into better accord with those found by other methods.

[1] E. O. Lawrence and M. Livingston. The Production of High Speed Ions without use of High Voltages. *Physical Review*, Vol. 40, 1932, pages 19-35.

[2] R. J. Van de Graaff. The Design, Operation, and Performance of the Round Hill Electrostatic Generator. *Physical Review*, Vol. 49, 1936, pages 761-776.

[3] R. A. Millikan. Electrons (+ and −), Protons, Photons, Neutrons, and Cosmic Rays. The University of Chicago Press, 1935, chapters III, IV, and V.

To the nucleus of the hydrogen atom has been given the name proton and to the negatively charged particle accompanying it, Millikan suggests that the term negatron be applied. In the early days of atom smashing—up to 1932—it was supposed that these two entities constituted the two building stones from which all atoms could be constructed, but on the night of August 2, 1932, Anderson, working in Millikan's laboratory, realized from a study of a cosmic ray photograph taken in the afternoon of the same day, that in this photograph he had positive evidence that another entity (another child) had been added to the electron family. So long as only a boy and a girl exists in the Smith family it is not difficult to distinguish between the two, but since Anderson's epochal discovery other definite particles of matter have been discovered among the wreckage of atoms and when the Smith family possesses two or more boys and two or more girls it will help in keeping their identity straight if they are named specifically, John, Jim, Mary, Alice, etc. The name positron has been given to the particle discovered by Anderson on August 2, 1932. It was one of the pieces left over in the smashing of an atom and, therefore, must have been a part of it originally. It carries a mass equal to that of the negatron, but positively charged with a quantity of electricity equal to that of the negatron, that is to say $(4.800 \pm 0.004) \times 10^{-10}$ electrostatic unit.

At this point it would be quite in order to quote from Millikan's recent book[4] the following footnote: "To remove the ambiguity in the definition of the term 'electron' existing at the present time because of the double sense in which it is used in the literature, namely, to denote on the one-hand—as for example in the universally used expression electron volts—the magnitude of the elementary quantity of electric charge, and on the other hand, the name of the particle of a particular mass, the terms 'negatron' and 'positron' are here used. These terms are used merely as convenient contractions for the fully descriptive particle designations, 'free negative electron' and 'free positive electron.' The term electron then retains its historical, derivative, and logical meaning as the name of the elementary unit of charge, and the present ambiguity no longer remains." The author understands by this statement that a distinguished authority on the electron theory of matter is saying that we should be specific in naming these particles which are the product of atomic disintegration. To that particle which has a mass of 1/1835 of that of a proton and carries a positive charge of $(4.800 \pm 0.004) \times 10^{-10}$ electrostatic unit, we have given the name, positron. Why should we not be logical and call that definite entity of matter a negatron whose mass is equal to that of the positron and carries a negative charge of $(4.800 \pm 0.004) \times 10^{-10}$ electrostatic unit? Such a procedure would keep us from the ambiguities in which so much of the present literature is engulfed and help those brought up on an older terminology to keep the present clearly in mind. The author also speaks from the experience of trying to teach undergraduates in colleges and helping them keep the numerous cataclysmic products straight in their minds.

By a series of brilliant discoveries in three different countries, a fourth member of the family of particles to be found in the wreckage of atoms was discovered. Bothe and Becker[5] at Giesen, Germany, found radiations from beryllium, when bombarded by alpha rays of polonium, which were several times more penetrating than the most energetic gamma rays of ThC″. In repeating these experiments, the Joliots[6] in Paris obtained other evidence that this was not an ordinary transfer of momentum, or else there was a violation of the laws of momentum and energy which had previously existed. Chadwick,[7] in the "mother laboratory of physics," the Cavendish Laboratory, pointed out that this difficulty could be overcome by saying that a particle without any charge but possessing the mass of a proton could bring about the effects observed in Germany and France. A real international set-up! Chadwick presented evidence that when the alpha particles from polonium struck the atoms of beryllium, there were knocked out of the nuclei of the beryllium atoms particles whose unit mass was equal to that of a proton, but not carrying any apparent charge. These particles were called neutrons: devoid of electrical charges.

Finally, Bainbridge[8] of Harvard University claims experimental evidence for another particle whose mass is that of either the negatron or the positron, but also devoid of an electric charge. This particle has been named the neutrino.

Search has been and is also being made for a sixth member of the electron family, namely, a particle whose mass is that of the proton or of the neutron, but carrying a negative electric charge of the same magnitude as the negatron, the positron and the proton. To it might be given the name anetron! If the latter particle is found there will be two triplets in the wreckage of atoms.

	+charge	—charge	No charge
Equal Mass	Proton		Neutron
Equal Mass	Positron	Negatron	Neutrino

It should be emphasized that all the charged particles carry electric charges of the same order of magnitude.

Darrow[9] has defined an atom as "a constellation of negative electrons, organized and held together by the attraction of a positive charge esconced upon a nucleus which is the center of the constellation and is many times more massive than all the electrons put together." Just where shall we put all the particles listed above?

In 1932, Urey and Murphy[10] of Columbia University discovered heavy hydrogen whose atom had a mass about twice that of ordinary hydrogen. This heavy hydrogen is called deuterium and its nucleus is called the deuteron, similar to protium, the name for light hydrogen, whose nucleus is called the proton. While the deuteron is one of the parts in the wreckage of an atom, nevertheless it is assumed that it consists of one proton and one neutron. Outside the nucleus there revolves one negatron just as in the case of the light hydrogen atom (protium). Chemically and spectroscopically, protium and deuterium are quite similar because the extra-nuclear negatrons are what determine the chemical and spectroscopic properties of the elements.

Still a third and heavier atom of hydrogen has been discovered whose mass is about three times that of protium. Its nucleus is supposed to consist of one proton and two neutrons with one extra-nuclear negatron as was found in the other two hydrogen atoms.

[4] R. A. Millikan. Electrons (+ and —), Protons, Photons, Neutrons, and Cosmic Rays. The University of Chicago Press, 1935, page 332.

[5] H. Becker and W. Bothe. Die in Bor und Beryllium erregten γ-strahlen. *Zeitschrift für Physik*, Vol. 76, 1932, pages 421-438.

[6] I. Curie and F. Joliot. Sur la Nature du Rayonnment Pénétrant Excité dans les Noyaux Légers par les Particules α. *Comptes Rendus*, Vol. 194, 1932, pages 1229-1232.

[7] J. Chadwick. Possible Existence of a Neutron. *Nature*, Vol. 129, 1932, page 312.

[8] K. T. Bainbridge. Science News, *Science*, Vol. 84, December 25, 1936, page 17.

[9] K. K. Darrow. The Renaissance of Physics. The Macmillan Company, 1936, page 193.

[10] H. C. Urey, F. C. Brickwedde and G. M. Murphy. A Hydrogen Isotope of Mass 2 and its Concentration. *Physical Review*, Vol. 40, 1932, pages 1-15.

Chadwick suggested in his first paper concerning the properties of the neutron that it might be thought of as a "close combination" of a proton and a negatron. For reasons beyond the scope of this work it would appear more reasonable to think of the neutron as a particle devoid of any electrical charge.

Following regular hydrogen in the series of 92 elements is helium with a mass of about four times that of protium. The helium atom is pictured as possessing two protons and two neutrons in its nucleus and with two negatrons outside the nucleus. The nucleus of helium is the well-known radiation from radium—the alpha particle.

To hydrogen with its one extra-nuclear negatron was given the atomic number, 1. Helium with two negatrons outside the nucleus has the atomic number, 2. For each negatron added to those outside the nucleus the atomic number increases by one until uranium is reached with ninety-two extra-nuclear negatrons and an atomic number of 92.

In a similar fashion consider lithium, the next element in the series. With three negatrons outside the nucleus, its atomic number is 3. Inasmuch as its mass is about six times that of protium it appears that there must be three protons and three neutrons in its nucleus. Still another lithium atom has been found whose atomic number remains 3 but in its nucleus another neutron has been added, which make the mass of this atom about seven times that of the light hydrogen. In this fashion one may progress through the series of elements until one arrives at uranium with its atomic number 92, indicating that there are 92 protons in the nucleus and since its mass is about 238 times that of light hydrogen there must be 146 neutrons also in the nucleus.

It will have been noted that several elements were mentioned whose atomic numbers were the same but had an excess of one or more neutrons in the nucleus over those in the regular elements in the series. Such elements are called isotopes. Thus in the three hydrogens, the only difference between them is in the number of neutrons in the nucleus. Protium has not any, deuterium has one and the still heavier hydrogen has two, but in all of them there is only one proton and one negatron.

The next question to be raised is, where do the neutrinos and the positrons fit into the picture of the atom? There are still conjectures on this point. Is the proton a combination of a neutron and a positron? Can the neutron and the negatron be made to unite? If so the anetron (?) will have been discovered. These are questions which still need to have more experimental confirmation and only make clear that we do not fully understand the architectural design of the atoms.

THE ATOM VIEWED MAGNETICALLY

The two Comptons[11, 12, 13] and their associates made some interesting experiments on the nature of the processes of magnetization and, therefore, threw added light on the picture of atomic structure. The first experiment was concerned with the Laue figures which were described in the preceding article. The question raised was, Would the Laue figures from iron crystals be affected by magnetizing the piece of iron used as a crystal grating? In magnetizing a bar of iron by placing it in a solenoid through which a direct current flows, it was assumed that in the process something like small magnets turned over and aligned themselves parallel to the magnetizing field. If the field in the solenoid was reversed, then these small magnets turned themselves over and pointed in the reverse direction.

It will be seen at once that this experiment raised the question as to the character of the *elementary magnet* turned over in the process of magnetization. What is this elementary magnet? If one holds a permanent magnet with the north pole in the right hand and the south pole in the left hand, what will happen if the magnet is broken in two? Will the north pole alone remain in the right hand and the south pole in the left? Everyone knows that breaking a magnet in two produces two complete bar magnets, the sum of whose lengths is just equal to the original bar. However, in a thought process, one could go on breaking each piece of the broken magnet into smaller and smaller pieces until finally one must come to a section which on breaking in two is no longer a complete magnet. What is that particle which does not yield two magnets on breaking it in two? Let us, for the present, call this particle the *magneton*.

If the iron atom has negatrons revolving about its nucleus like the planets about the sun, then these revolving negatrons would be like the coils of a d'Arsonval galvanometer in which a direct current is flowing: they both would swing with the planes in which the electric charges are moving at right angles to the magnetic field in which they find themselves. If an atom of iron is like that, the Comptons reasoned, then the Laue figure would be different when the iron was magnetized from what it is when the iron is in the unmagnetized condition, because if the atom as a whole turned there should be a difference in the diffraction pattern due to the change in the distances between the centers of the atoms.

No difference in the Laue figures could be detected when the iron was magnetized to saturation as compared with the unmagnetized state. The experiment, therefore, led to the point of view that what turned over in the process of magnetization were the extra-nuclear negatrons which, as spinning tops (gyroscopes) gave the magnetic effects observed in iron when it is magnetized.

The second experiment was, however, more convincingly in favor of the point of view that the negatrons *spinning on their own axes* were the magnetons, and not the orbital movements of the negatrons as postulated by Bohr. If the negatrons had been revolving about the nuclei of the iron atoms, as was pictured by Bohr, and the planes of these orbits had been turned in the body of the iron, then a change in the intensity of the radiation of X-rays from an iron *target* bombarded by negatrons should have resulted whenever the iron was magnetized or demagnetized. No effect could be observed in this experiment. Both experiments, therefore, led to the proposition that the magneton is a negatron spinning on its own axis like a gyroscope.

While these experiments do not preclude the orbital negatrons from our picture of the atom, it certainly makes them less necessary for our picture; which is a score in favor of the chemist's picture given by Langmuir, who thought of the negatrons as fixed in space with respect to the nucleus of the atom. However, it should be stated that spectroscopic evidence rather calls for orbital negatrons.

The Barnetts[14] also performed an experiment which fits into the picture made by the Comptons. If the magnetons in iron are negatrons spinning on their own axes like gyrostats, then they should behave like gyrostats. This is what the Barnetts found to be the case: They

[11] K. T. Compton and E. A. Trousdale. *Physical Review*, Vol. 5, 1915, pages 315-318.

[12] A. H. Compton and O. Rognley. The Nature of the Ultimate Magnetic Particle. *Science*, Vol. 46, 1917, pages 415-416.

[13] A. H. Compton and O. Rognley. Is the Atom the Ultimate Magnetic Particle? *Physical Review*, Vol. 16, 1920, pages 464-476.

[14] S. J. and L. J. H. Barnett. New Researches on the Magnetization of Ferromagnetic Substances by Rotation and the Nature of the Elementary Magnet. *Proceedings American Academy of Science*, Vol. 60, 1925, pages 127-216.

ated a long cylinder of iron in a space free of all magnetic fields and discovered that the bar of iron became a magnet. When they reversed the direction of magnetization, the direction of magnetization was also reversed just as one would expect from such a group of gyrostats, as this is the principle on which the gyrocompass acts when it sets its axis of spin parallel to the axis of rotation of the earth and thus always points north.

From the standpoint of atomic structure, from the theory regarding magnetization, and from the relation between hardness and magnetization, these experiments of the Comptons and the Barnetts appear as highly important and illuminating suggestions as to what goes on in iron when it is magnetized.

The preceding experiments portrayed more particularly the physicist's concept of the atom. The chemist has felt the need of an atom in which the negatrons "stayed put" in their relations to the nucleus. This idea

Fig. 21. One end of a bar magnet is brought up under a plate of glass. The steel balls arrange themselves in symmetrical design under the influence of the magnetic field. The large ball represents the nucleus and the smaller balls the negatrons, the extra-nuclear negatrons of an atom. This equilibrium figure may represent an atom of nitrogen, atomic number = 7.

is sometimes referred to as the static electron concept. The outstanding picture has been given by Langmuir[15] and is reviewed here because it has been valuable in helping us to recognize many relations and properties of chemical substances which we would not have observed without Langmuir's help. It is interesting to note that the spinning negatron idea suggested by the Comptons is not inconsistent with the fixed negatron of the chemist.

Before taking up the Langmuir model of the atom, notice should be called to some equilibrium figures by Wood.[16] Figs. 21 and 22 indicate some modifications of the figures. They show how by a combination of magnetic forces at least these figures of equilibrium may be established and thus suggest possible atomic equilibrium adjustments between the nucleus of the atom and its satellites. Bethe, of Cornell University, has just announced that there are forces within the nucleus of the atom which hold protons to protons, neutrons to neutrons, and neutrons to protons, which are many times greater than the calculated gravitational, electrical or magnetic forces would be. Wood magnetized a large number of steel balls to form permanent magnets. These were floated on the surface of a dish of mercury, like the needles stuck in corks and shown in Fig. 22 are floated on the surface of a dish of water. On bringing the north pole of a bar magnet near these floating ball magnets, all of the south poles of the steel balls are turned toward the

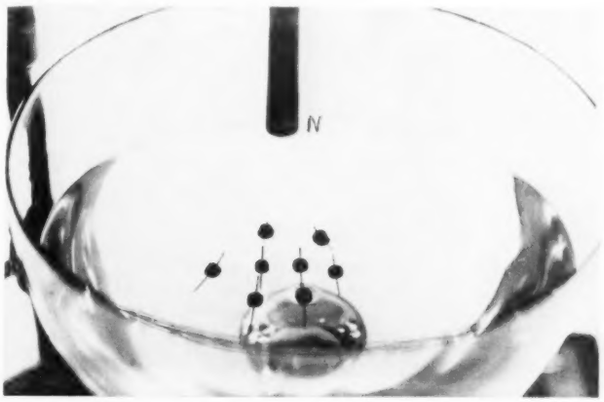

Fig. 22. A study of the arrangement of extra-nuclear negatrons may be made with needles stuck in corks and floated on water. The bar of the magnet producing the field is shown above the needles.

bar magnet. Under the attraction of the bar magnets and the mutual repulsions of the poles of the steel balls, the balls arrange themselves in geometrical figures as shown in Fig. 21. In a solid aggregate, of course, it would be necessary to consider the geometrical design, shown in Fig. 21, as being applied to three-dimensional space. At best this is only a crude picture of the design of the inner parts of an atom. In addition to the electrical and magnetic forces, there is still the force of gravity acting as another factor in holding together the constituent parts of the crystal and of the atom.

THE LEWIS-LANGMUIR CONCEPTION OF THE ATOM

Perhaps the most helpful theory in thinking about the arrangement of the extra-nuclear electrons in the atom is the idea of shells of negatrons. Lewis[17,18] and Langmuir[15] have been particularly active in developing this theory, which shows new relations between substances that had not been previously suspected. Langmuir presented the idea that the extra-nuclear or valence negatrons are at the corners of a series of cubes or shells surrounding the nuclei of the atoms. These shells or cubes are called the K, L, M, N, O, etc., shells as one proceeds from the innermost one outwards. The negatrons at the various corners of the shells may be thought of as the spinning gyroscopes already suggested. A study of any periodic table of the elements discloses that the factor 8 plays an important rôle in their arrangement (after the start, where the factor 2 calls for a closed shell). When an atom has all of the corners of its outer shell occupied by valence negatrons, it seems to be satisfied and is a chemically inactive (inert) element. Langmuir has shown (see Fig. 23) how the valence negatrons

Continued on page 82

[15] I. Langmuir. The Arrangement of Electrons in Atoms and Molecules. *Journal American Chemical Society*, Vol. 41, 1919, pages 868-934.

[16] R. W. Wood. Equilibrium Figures. *Philosophical Magazine*, Vol. 46, 1898, pages 162-164.

[17] G. N. Lewis. Valence and the Structure of Atoms and Molecules. American Chemical Society Monograph, 1923.

[18] G. N. Lewis. The Magnetochemical Theory. *Chemical Reviews*, Vol. 1, 1924, pages 231-248.

Cathode-ray Oscillograph Applications

Twenty-first part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in July 1937 issue.

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AUTOMOTIVE TESTS

IGNITION STUDIES

A cathode-ray tube can be used effectively in connection with several problems connected with automotive inspection tests. Of these a common problem is that concerned with ignition.[1-4] An ignition coil discharge is not the simple phenomenon that is usually assumed: oscillograms will show many complex surges which may have little or much to do with the problem at hand, that of igniting the gaseous mixture, but which contribute much to initiating radio wave disturbances. In the usual coil design, a large self-capacitance is inevitable with the secondary winding which, being periodically charged with a high voltage, discharges with a highly damped surge. This surge, useless insofar as the production of a hot spark is concerned, is capable of shock-exciting the attached circuits into oscillations of an extremely high frequency. Other problems in this field have to do with the study of optimum ignition characteristics at high engine speeds. An extremely short interval of time for building up the magnetic field in the coil is perforce available at such speeds, especially in cars with eight or more cylinders.

These ignition problems are within the scope of a modern high-voltage cathode-ray oscillograph. Voltages in excess of several kilovolts are required in order to disclose adequately the duration and extent of the surges involved, by reason of their high transverse speed across the screen.

In most tests it is necessary to synchronize the horizontal deflection with engine revolutions. A linear sweep oscillator interlocked with pulses from the ignition coil primary circuit can be used if a direct mechanically controlled indicator cannot be applied. These synchronizing pulses can be obtained either from an electromagnet placed near one end of the ignition coil, or from leads connected across the breaker point condenser. In either case the polarity of the received pulses can be reversed so that the desired portion of the surges appears centrally on the oscillogram.

In many oscillographs the effectiveness and adaptability of the interlock control is sufficiently accurate for the sweep to be triggered off every fourth, sixth or eighth pulse (or as required for the engine being tested). Otherwise this arrangement will give one sweep for each firing interval. This latter arrangement is particularly useful for showing up variations between cylinders, as all oscillograms are superposed and significant differences are immediately apparent.

Connections to the high-tension circuit can be made in several ways:

1. Connect the deflection plates to a small piece of tin or copper foil (wrapped around a section of the high-tension cable) and to ground. If the cable to the center arm of the distributor is used, one surge of course is received each time one of the cylinders fires. Or a particular spark plug can be tested by connecting to the cable to that plug. The capacity currents through the cable insulation are sufficient to give the necessary deflection without amplification, if the foil area is sufficiently large.

2. Connect directly to the spark plug under test through a high resistance (say ten to twenty megohms) and to ground. The plates themselves should be shunted with a variable resistance having a value of around 50,000 ohms maximum, to permit control of the deflection amplitude.

3. A magnetic pick-up coil can be placed near the ignition coil.

Each of these connection arrangements produces a different type of oscillogram. All should be tried in order to select the one that gives the best indication of the effect under investigation. The first method shows the high-frequency highly-damped wave that occurs at the beginning of the spark interval. Method 2 usually shows some of this effect and in addition indicates the duration of the spark.

The effectiveness of the primary condenser capacity, breaker point clearance, relative efficiency of coils, or of radio interference suppressors, etc., is immediately apparent with these set-ups. Synchronization of the discharges in dual ignition circuits, or where two sets of breaker points are found, can be visually indicated as well.

These test can all be made with ordinary commercial oscillographs although some sort of recording camera may be desirable for research work. In certain instances, however, the use of staged tests may be desirable. For example in the matter of ignition coil efficiency a coil, a spark plug and a motor-driven shaft carrying the breaker arm can be mounted on a bench, with provision on the shaft to synchronize the time base of the oscillograph. Many variations of this type of test can be made in a short time: two types of coils can be compared, optimum condenser capacity determined, gap length variations

Fig. 1

[1]Tooke, Finch & Sutton. Timing Wave Oscillator for Irregularly Recurring Phenomena. *Proceedings Physical Society of London*, Vol. 43, 1931, pages 502-511.

[2]Finch & Sutton. Cathode-ray Method for the Measurement of Inductance. *Proceedings Physical Society of London*, Vol. 44, 1932, pages 190-194.

[3]Finch & Sutton. Control of Ignition Coil Discharge Characteristics. *Proceedings Physical Society of London*, Vol. 45, 1933, pages 288-307.

[4]Woonton. Viewing Induction Coil Transients. *Canadian Journal of Research*, Vol. 12, 1934, pages 272-275.

d under the conditions of various cylinder pres-
s, etc.

In view of the problems associated with the satisfac-
y control of ignition characteristics in the case of
high-speed engines, even small improvements in coil
operation may contribute major gains in efficiency. That
ignition coil design is complicated by many factors has
come to be realized—and this research-mindedness means
that greater strides will now be made in the development
of maximum efficiency at high speeds with minimum
radio interference. Some of these factors are:

At the higher speeds of a modern car the primary current may never build up to its full value. The duration of the spark, depending entirely upon the circuit constants, may extend greatly beyond the useful period which is the time required for the gas to become fully ignited. The secondary is usually unloaded while the primary current is flowing, so that maximum inductance occurs in the primary during this interval. At the beginning of the spark the secondary is still unloaded,

Fig. 2

except for the capacity of the secondary winding and cables. When secondary current starts to flow, this capacity discharge takes place in the form of a high-frequency damped wave until the ionized gas across the spark gap reduces the secondary load resistance to a relatively small and constant value which lasts as long as the spark continues. The capacity surge that occurs before the main spark starts contributes most toward the production of radio interference and least toward increasing the ignition properties of the spark.

Thus it is seen that the problem presents many aspects that can be analyzed with an oscillograph, and the above-mentioned effects are listed here to assist in analyzing the oscillograms that may result.

Automobile spark plug interference suppressors are usually considered as causing no ignition losses, but this is not the case with some types. The radio disturbances that are so produced not only spoil reception on a receiver installed in the same car, but cause interference in other receivers many hundreds of feet away, which retards the popularity of radio reception on many short-wave channels.

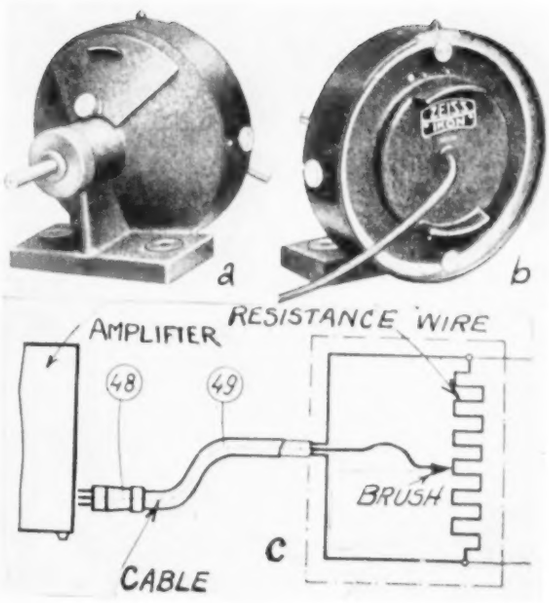

Fig. 3

This very trouble, however, suggests the method of utilizing a radio receiver as the obvious means of picking up and amplifying ignition surges for oscillographic study, in connection with engine tune-up. As stated before, the amplitude of the ignition interference as picked up by such a receiver does not indicate the characteristics of the surge that produces ignition, but nevertheless the time interval between successive pulses is correctly delineated—which is all that is required for some tests. If the time base is operating synchronously it can be readily ascertained if these pulses are equally spaced and, when two sets of breaker points operate alternately, whether there is the proper time interval between them.

PRESSURE INDICATORS[5-9]

A solution to the problem of delineation of pressure-time curves in compression and combustion cylinders, by oscillographic methods, has been undertaken by a number of investigators. In general this test consists of the application of a pressure converter, of some type described in the June, 1936, article, to a particular cylinder, and its connection through an amplifier to the vertical deflection system. Horizontal deflection potentials are obtained in a manner similar to those used with the above-described ignition tests. A commercial example of a pressure converter similar in principle to that shown in Fig. 5 of the June, 1936, instalment, is shown in Fig. 1. It is a part of the Zeiss-Ikon (German) motor indicator system* and is shown with a standard spark plug for comparison. Fig. 2 shows two views of the camera-oscillograph of this system, which may be used in either a visual or a photographic analysis, since the camera attachment (pre-focused) can be quickly lowered into position. A rotating variable-resistor, Fig. 3, must be con-

[5]DeJuhasz, Engine Indicators, *Instruments*, Vol. 6, 1933, pages 27-29 and 46.

[6]Kaufmann, Pressure Indicators, *Archiv Für Technisches Messen*, July 1931, page T7.

[7]Kluge & Linkh, Piezoelectric Devices, *Archiv Für Technisches Messen*, Sept. 1932, page T133.

[8]Gehlen, Measurement of Oscillating Pressures, *Archiv Für Technisches Messen*, Dec. 1931, page T81.

[9]Aeronautical Research Institute, Report No. 7, Indicators for Combustion Engines, *Scientific Papers of Institute of Physical & Chemical Research*.

*Photographs courtesy Geo. Scherr Co., New York City, American agents.

nected directly to the crankshaft to produce the horizontal deflection. This apparatus has a carefully balanced rotating element to insure smooth operation at high speeds and mechanical wear is localized on a replaceable soft-metal contact pin on the rotating arm to reduce the wear on the resistance wire element. Fig. 3c shows the wiring system. The whole head of this resistance element can be rotated (see Fig. 3b) to correct for any angular displacement due to connections. A surge amplifier is used (see Fig. 4) to connect the output of

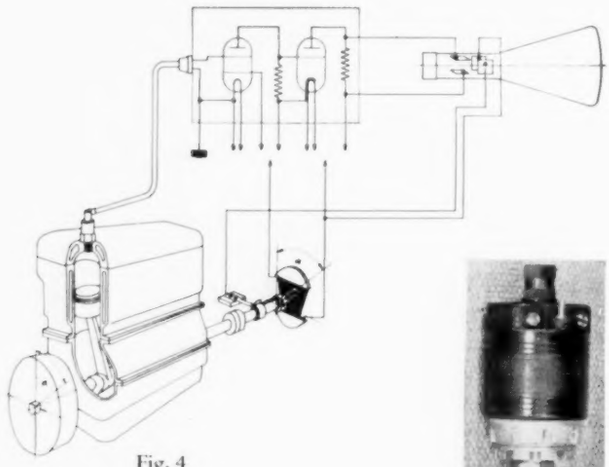

Fig. 4

Fig. 6

the piezoelectric converter to the deflection system. This amplifier is not unlike that shown in Fig. 49 of the May, 1936, article, except that a different type of input is required.

Assuming that the quartz plate (quartz is representative of all types of piezoelectric crystals, and is generally used in these applications on account of its ability to withstand crushing pressures*) is properly cut with respect to the axes of the original crystal, the charge that appears on its faces is at all times directly proportional to the pressure. If the pressure varies the charge will vary accordingly. If there is no path provided whereby this charge can leak away, the potential difference between the two faces will be inversely proportional to the capacity of the element, considered as a small quartz dielectric fixed capacitor. If any external capacitances are connected in parallel with the piezo element, the potential difference is of course reduced. In connecting an amplifier to any type of piezoelectric converter, therefore, it is necessary to avoid any resistance shunts if possible. There will be some leakage loss across the vacuum tube itself, especially if ordinary receiving type tubes are used, and in addition it will usually be necessary to provide an external grid leak, to prevent the grid from collecting a charge due to its own operating circuit potentials.

Investigators have therefore usually applied one or more of the following expedients in setting up this amplifier:

1. Use of a special low grid current amplifier tube, such as the FP 54 (G.E.Co.) or the RJ-550 and RJ-558 (Westinghouse Lamp Co.);

2. Use of a standard tube with low anode potentials and extremely high grid input resistance (10 megohms);

3. Use of a large shunting capacity across the crystal to minimize the loading effect;

4. Use of a tetrode or pentode tube input stage connected as a space-charge amplifier with a high input resistance.

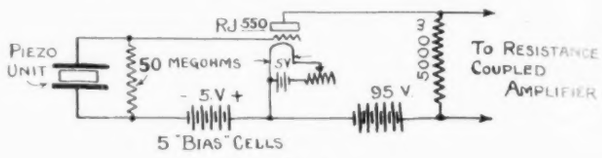

Fig. 5

An electrometer type of amplifier or coupling tube, requiring an extremely low anode potential, can be used as the input tube in the piezoelectric amplifier. The input resistance to this tube can be practically infinite ($>10^{5}$ megohms). Other tubes are available, however, that will function satisfactorily as a coupling tube, giving higher gains than the electrometer tubes. A representative type is the Westinghouse type RJ-550, used in the circuit shown in Fig. 5. This stage can be used with local battery power supplies, with bias cells (one volt each) in the input circuit. This stage can be coupled into any amplifier capable of operating at the frequencies at hand.

In the above-mentioned Zeiss equipment, changes in the calibration constant for the various operating conditions is accomplished by the insertion of a selected shunt capacity across the crystal. In another amplifier and sweep system used by Drs. Kluge and Linkh[7] for such tests, a space charge connection is used with the first tube.

A high-speed engine pressure indicator element developed by the Commercial Engineering Laboratories of Detroit is shown in Fig. 6.

In mounting the crystals care must be taken so that the charges that appear across opposite faces are not shorted by the mounting holder. If more than one crystal is used, the faces having same polarity must be connected to the same terminal.

It is not difficult to superimpose pulses from the ignition circuit on the same pressure time curves. In fact, unless special shielding precautions are observed, such surges often are unintentionally present.

To be continued

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Selection of the Correct Valve Types and Sizes for Automatic Flow Control Applications

This is a *new* portion of Béhar's Manual of Instrumentation (Section 9 of Chapter XXVIII in Part Six). It is published at this time on account of its timeliness: Mr. Smith completed it less than a month ago.

Part Six was published serially in *Instruments* throughout 1932 and 1933 in the form of twenty-four consecutive articles by M. F. Béhar, all of them entitled "Flow Measurement and Control." It has been undergoing considerable expansion, Mr. Smith being one of the co-authors contributing new material especially written for this handbook. It is to be issued in book form in a few months.

By ED S. SMITH, Jr.
Hydraulic Engineer, C. J. Tagliabue Mfg. Co.,
Brooklyn, N. Y.

The resistance of a control valve is only a part of that of the hydraulic circuit regulated. To control the flow, it is necessary that the valve have enough resistance to dominate the circuit under the required range of conditions. The following notes are pertinent here, even though they might prove to be rather elementary notes on hydraulics to engineers constantly working in this field. These notes have been prepared and edited with the *user* in mind—not from the standpoint of the designer or manufacturer of flow meters or of valves.

For many purposes, it is satisfactory to use a valve having a practically linear relation between opening and discharge when it forms the only appreciable resistance in the circuit. The reason for this may appear from a study of the following typical industrial applications.

For a circuit having high friction losses, a plotted curve of the relation of discharge against valve travel should be non-linear, rising rapidly at large openings: such a curve as is given roughly by a valve having an equal percentage increase per unit movement of the valve.

As a start, assume that the effect of installation is zero. Consider an infinitely large reservoir having a vertical side containing a parallel-sided horizontal slot partially closed by a sluice gate. The discharge will be substantially proportional to the opening. Indeed, this simple device has been used from early in history to the present for apportioning water from a common supply for irrigating a number of separately owned farms.

(a) Gravity Flow in a Short Pipe.

As soon as the control valve is put into a pipe, two things must be considered: (1) the effect of the velocity of approach and (2) the characteristics of the flow meter that commands this control valve.

(1) Even without friction loss in the pipe and with a wide-open control valve, the discharge Q will be limited to a value corresponding with the head H, assuming uniform parallel flow in the pipe,

$$Q = A_1 \sqrt{2g\,H} \qquad (1)$$

or

$$H_1 = V_1^2/2g \qquad (2)$$

With a valve of rectangular cross-section, the area A of opening is proportional to the amount of opening. Starting with such a valve closed, the discharge will increase practically in proportion to the area A until the valve is well open, when the effect of the velocity of approach is felt. The entrance loss H_1 is as in equation (2), while the loss across the valve is substantially

$$H_v = (A_1/A - 1)^2\, V_1^2/2g = k'\, V_1^2/2g \qquad (3)$$

The total head H is the sum of the entrance loss H_1 and the valve loss H_v, or

$$H = V_1^2/2g + (A_1/A - 1)^2 V_1^2/2g \qquad (4)$$

$$H = [(A_1/A)^2 - 2A_1/A + 2]\; V_1^2/2g = \frac{k V_1^2}{2g} \qquad (5)$$

where k is the friction factor for the valve, including the velocity-head in the pipe. Then, the discharge

$$Q = A_1 V_1 = C\, A_1 \sqrt{2gH} \qquad (6)$$

where $a = A/A_1$ $\qquad C = a / \sqrt{1 - 2a + 2a^2}$ (7)

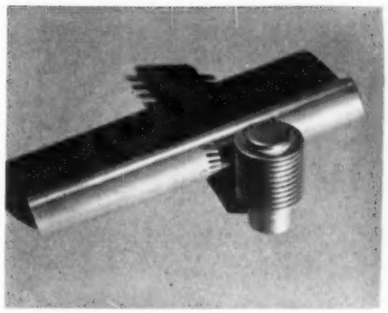

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TABLE XXVIII—1. RELATION OF AREA RATIO *a*, COEFFICIENT C AND FRICTION FACTORS *k* AND *k'*

a	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C	0	0.110	0.243	0.394	0.555	0.707	0.832	0.919	0.970	0.994	1.00
k	∞	82	17	6.44	3.25	2.00	1.44	1.18	1.06	1.01	1.00
k'	∞	81	16	5.44	2.25	1.00	0.44	0.18	0.06	0.01	0

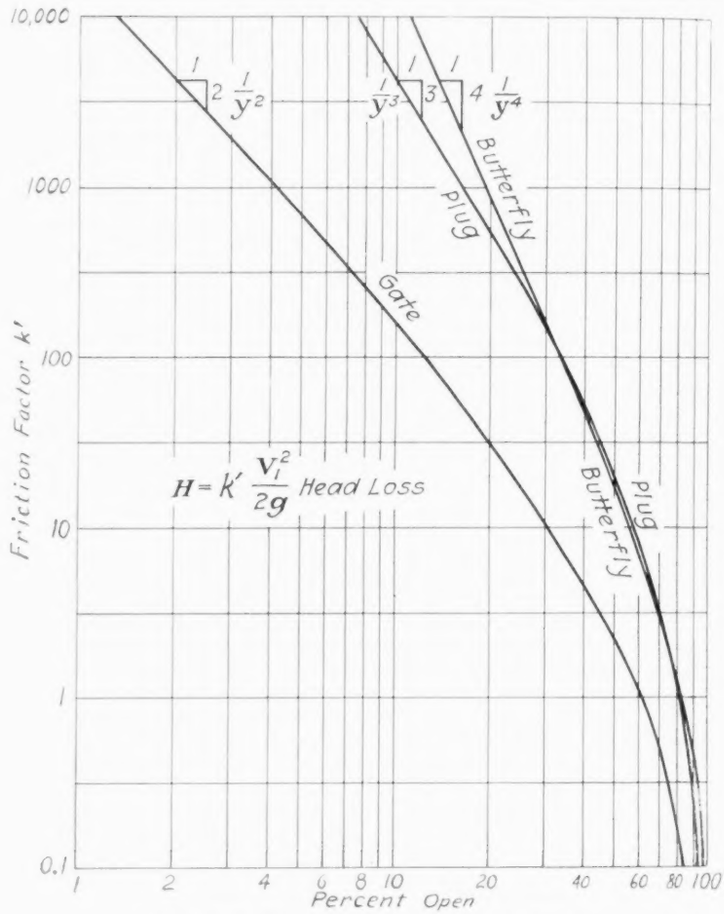

Fig. 28-10. Typical Characteristics of Valves.
Courtesy American Society of Mechanical Engineers

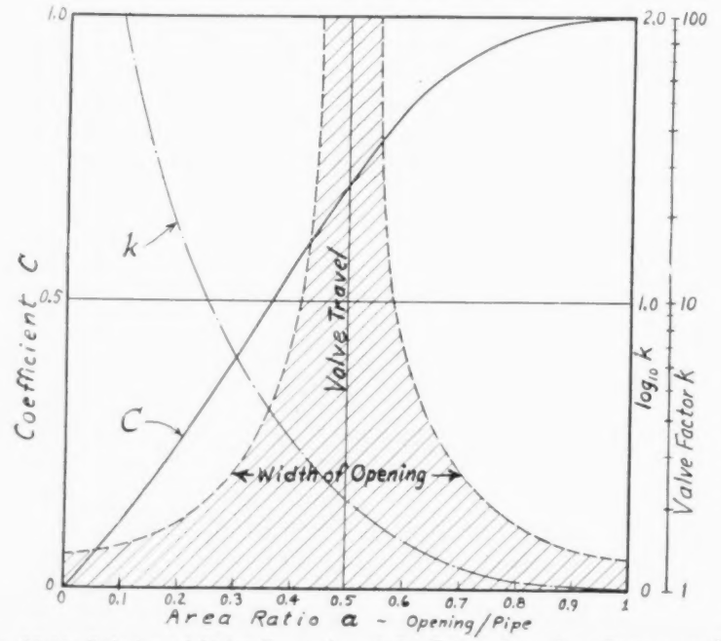

Fig. 28-11. Relation of Valve Factor *k* and Coefficient C to Area Ratio *a*; and the shape of valve opening for Uniform Stability.

In the whole, it appears that while it is necessary to treat a valve from the standpoint of its resistance in conjunction with the other resistances in the hydraulic circuit, it also is necessary to consider the effective area of the orifice of the valve just as though the control valve itself was a flow meter. In other words, the resistance is expressed by the product of the valve's "friction factor" k by the velocity-head of the flow in the pipe; this k being subject to such wide variations that it is best expressed by its $\log_{10}$. And the less-variable "coefficient" C, expressing the ratio of effective area to pipe area, is related simply according to equation (7) with the area ratio a. The coefficient C and the friction factor k, including the velocity head in the pipe, is

$$k = 1/C^2 \qquad (7a)$$

The characteristic relation of friction factor k' to valve opening for several typical valves is shown in Fig. 28-10.

(2) The usual differential type flow meter is somewhat more sluggish at low rates than at high. Consequently the width of the opening should be reduced when nearly closed, so that there is no excessive tendency to hunt with a nearly closed valve. In Fig. 28-11, the solid line shows the value of C from the above table while the dotted line shows the shape of slot required to give fairly stable performance of control valve with a usual flow meter governing its action. The dot-dash line shows the value of k for the parallel walled slot valve of the table. Of course, the foregoing analysis is oversimplified in several ways.

(b) Gravity Flow in a Long Horizontal Line.

To obtain reasonably satisfactory regulation with a discharge range of 1:5 with turbulent flow in a long horizontal line fed by gravity and discharging to the atmosphere through a variable demand valve, the control valve's design may be made as below:

line friction	aq^2		(8)
demand valve loss	bq^2		(9)
control valve loss	cq^2		(10)
Total head	$H = (a + b + c)\, q^2$		(11)
	$= (a + b) + c_1$	for $q_1 = 1$	(12)
	$= 25\ (a + b) + 25c_2$	$q_2 = 5$	(13)
	$c_1 = 24\ (a + b) + 25c_2$		(14)
or	$c_1 = 24\ (a + b + c_2)$	(approximately)	(15)

In other words, with one-fifth of the maximum flow and the same head, the friction factor c_1 must equal approximately 24 times the friction factor for the entire line, including the wide-open control valve.

Further, assume that the head can vary over a range of 1:4, or from 10 to 40 feet. With wide-open valve, one extreme condition exists with maximum flow at 10-ft. head. With valve most nearly closed, the other extreme condition exists with minimum flow at 40-ft. head; then

most nearly closed	$4H = (a + b) + c_1$	(16)
wide open	$H = 25\ (a + b) + 25c_2$	(17)
	$c_1 = 99\ (a + b) + 100c_2$	(18)
or approximately	$c_1 = 99\ (a + b + c_2)$	(19)

Thus the friction factor for the control valve must vary from about 1 to 100 to meet a discharge range of from 1:5 and a head range of 1:4.

For positiveness of control, it would possibly be ideal to have a unit displacement of the valve able to affect equally the discharge under any combination of discharge and head within the above-mentioned ranges, even without considering stability. When valve stability is necessary (for instance to avoid the possibility of water hammer with a long line carrying a liquid) it is even more important to have a unit displacement of the valve produce a constant-percentage change of the discharge rate set. Without making a formal mathematical analysis, the following qualitative observations apply to this case: When the control valve is nearly wide open and the discharge is determined mainly by the friction in the line, the regulation tends to be highly stable relative to that for a nearly-closed valve, as is apparent from inspection of Fig. 28-12 showing head lost across valve plotted against discharge.

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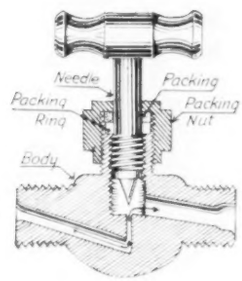

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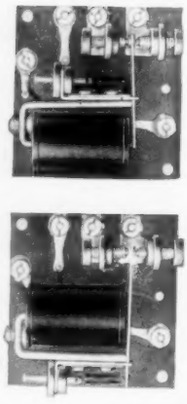

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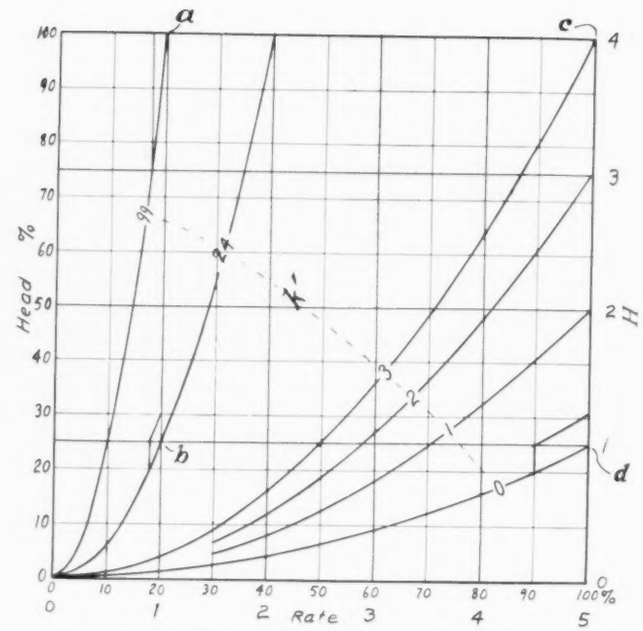

Fig. 28-12. Head Loss Across Valve.

Fig. 28-13 shows the relation between the valve friction factor k' and the area ratio of the opening A to A_1, that of the pipe. The head lost across the valve is

$$H_v = (A_1/A - 1)^2 V_1^2/2g = k'V_1^2/2g \qquad (3)$$

$$A/A_1 = \frac{1}{1 + \sqrt{k'}} \qquad (20)$$

and, considering the fluid discharged:

for water in large lines $Q = 8.02\, A_1 \sqrt{H/k'}$ ft³/sec. (21)

for liquids $q = 300 \dfrac{a_1}{\sqrt{k'}} \sqrt{p/w}$ gal/min. (22)

where a_1 pipe section in.²
p head lbs./in.²
w density lbs./ft.³
and 231 in.³ = 1 gal. (US)

for steam and gas $W = 2{,}400\, a_1 \sqrt{pw/k'}$ lbs./hr. (23)

for air and gas (dry) $Q_s = 24.34 a_1 \dfrac{T_s}{P_s} \sqrt{(p\, P_a/k'\, s\, T_a)}$ ft.³/min. (24)

of free gas at standard conditions P_s and T_s
with actual down-stream conditions P_a and T_a
and s = specific gravity of gas based on air = 1.

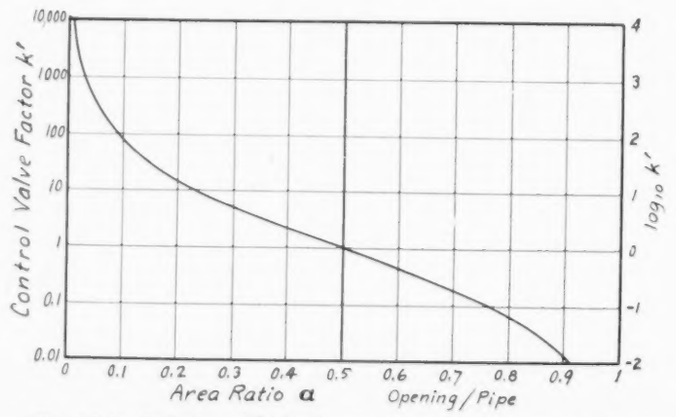

Fig. 28-13. Relation of Valve Factor to its opening area ratio a.

Fig. 28-14 gives the typical shape of slot opening in a piston valve suited for controlling flow under the conditions existing in Fig. 28-12. The dotted line shows the relation between theoretical travel and total area of opening, based on Figs. 28-12 and 28-13.

This general method is not claimed to be rigorous, but it does give a fair basis for obtaining a valve speed that will result in nearly uniform stability under the required range of conditions. It will be observed that the travel has been extended about 10% over the theoretical at each end of the stroke: at the

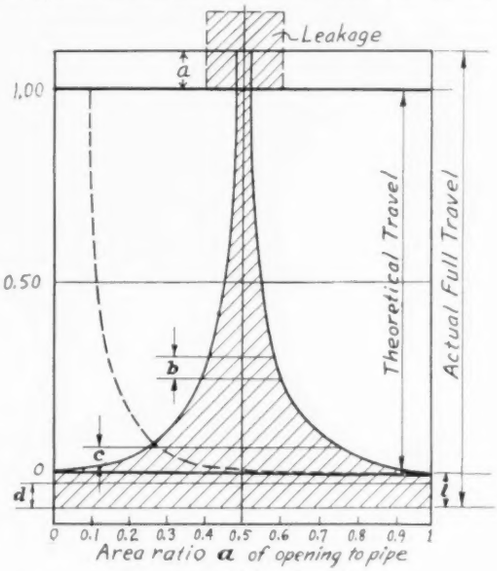

Fig. 28-14. Valve Opening.

closing end to give enough flow to take care of minimum requirements, and at the opening end the wide slot extended "l" distance provides enough area to lower the friction loss across the valve to any specified amount within reason.

Referring to each corner of the field of conditions in Fig. 28-12, the following table shows the valve movement, assuming k proportional to valve travel, necessary to correct for a 10% decrease in flow.

TABLE XXVIII—2

	Q	H	k'	$\Delta k'$	A/A_1	$\Delta A/A_1$
a	1	4	122.5	23.5	0.08	0.01
			99		0.09	
b	1	1	29.9	5.9	0.15	0.015
			24		0.165	
c	5	4	3.94	0.94	0.335	0.025
			3.0		0.36	
d	5	1	0.25	0.25	0.665	0.335
			0		1.000	

In connection with flow meters used for commanding valves, it should be observed that the meter is much more sluggish at low rates, and that this extra time is used by the increased valve travel at the closing end, due to the narrow slot (plus leakage) there.

(c) Boiler Feed With Centrifugal Pump.

To illustrate the effect of the type of pump on the regulation problem, consider the case where a centrifugal pump feeds a boiler and the control valve is required to maintain the desired flow rate with a minimum of power lost in pumping. Assume the boiler pressure to be 95 lbs./in.² with the accompanying pump characteristic curve for a given pump speed. It is apparent that the pump speed should be at least enough to start flow against the boiler pressure without special valve manipulation such as may be required with steam injectors.

To maintain flows ranging from a maximum rate to one-sixth of the maximum (a common range) a valve is required having a "wide" range. Assume the friction in the piping with a wide-open control valve to be 5 lbs./in.², including 1 lb./in.² loss in the valve itself at the maximum rate of 60 gal./min. At the minimum rate of 10 gal./min., the loss due to the valve is, from the graph in Fig. 28-15, 12 lbs./in.², so that the friction factor k' of the valve varies from 1/36 to 12, a range of 1:432!

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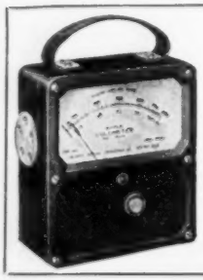

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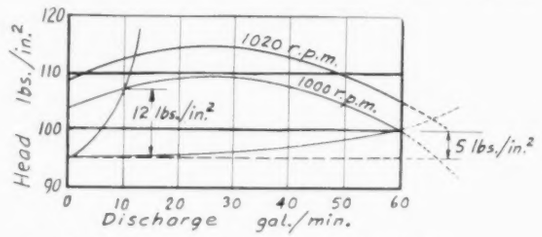
Also, the least change of pump speed requires a much larger change of valve. While the line friction is small relative to the boiler pressure, the valve loss is likewise small so that maintaining stability is difficult chiefly insofar as the variations in boiler pressure or pump speed introduce uncertainties.

For boiler feed regulators, it is necessary in practice to maintain a fixed pressure drop across the control valve. Then the flow rate depends only upon the opening of the control valve. For modern boilers having high ratings, the control valve maintains an input rate proportional to the steam output as determined by a steam flow meter, with (in some instances) a correction for the water level in the boiler. In others, the ratio of air flow and water input is kept in balance. For such high-duty boilers, the water storage possible in the drums is so small that the control valve must act extremely rapidly to keep



Figs. 28-15. Centrifugal pump for boiler feed.

pace with the lively changes of level with changes in steam demand. With certain centrifugal pumps, the head first increases and then drops off with increase of discharge. In such cases, there is the possibility that either of two discharges may exist for a given head. To avoid this condition so antagonistic to proper governing, it is customary to install the control valve so as to maintain a constant differential across it and vary the opening according to the level.

It is more economical to control the speed of the pump than to throttle its discharge—especially with a steam-operated pump. However, there is some storage of steam between the control valve and the pump and this storage (a typical source of "application lag") brings about a tendency to hunt. Consequently a high type of regulator must be used for controlling the steam flow.

Although the boiler feed regulator is up against a severe task in several ways as above pointed out, another case calls for an even wider range of valve action: the heating of a large insulated vat. A relatively large flow of steam is required to bring it up to the desired temperature within a "reasonable" time, and a relatively small flow of steam is required to keep the vat at the set temperature after this temperature has been reached. This valve problem is in addition to the problem of stable control which also exists, but in many cases it is unnecessary to have the valve stable as long as the temperature stays near that required.

Valves for gaseous fluids should have increasing flow passages as the fluid goes through, so that the expansion will not unduly limit the capacity of the valve as the downstream pressure falls below about 56% of the absolute pressure at its inlet. A safe but rough rule is to figure the discharge as the square root of the pressure differential at higher downstream pressures and use the 56% value for all downstream pressures below this 56%, *i.e.*, assume that the flow will not be increased at all by further drops in the downstream pressure.

It is thus seen that the relations involved are not complex as compared with those involved in flow metering, being in fact the same relations. Although more trouble is had due to the expansibility of gaseous fluids with the more severe pressures changes, still the velocities are generally so high that there is considerably less difficulty due to changes of coefficient due to viscosity. Where air is likely to come out of solution, where liquids flash into vapor with release of pressure, etc., the valve capacity must be considered as subject to at least partial "blocking" by the gaseous fluid, much as with the purely gaseous fluid flow.

(d) Streamline First-power Flow.

Cases are met with, also, in which streamline viscous flow exists. This occurs in pipe lines for heavy oils, in heat exchangers and in water filtration plants. Taking the latter case, an instance of wide application, because of its exacting requirements for high accuracy, speed and stability, it immediately appears that the self-operating controller ("direct-acting controller" to waterworks men) meets these requirements so well that it should be given preference for the smaller sizes and the upper limit stretched as far as possible.

TABLE XXVIII—3 LOSSES IN FILTRATION BED, PIPING AND CONTROL VALVE

	Max. Rate 1000 gal./min.		Min. Rate 250 gal./min.	
bed condition	clean	dirty	clean	dirty*
bed	ft. 2	12	0.5	3.0
piping	ft. 2	2	0.125	0.125
control valve	ft. 12	2	15.375	12.875
total	ft. 16	16	16	16
friction factor	k' 0.75	0.125	15.375	12.875

*The bed should not become too dirty to meet capacity requirement in case of fire.

Consider a plant having the water on the filters 16 ft. above the level in the clearwell, a loss of head in the filter of 2 ft. when the bed is clean and 12 ft. when dirty, just before washing. The valve's loss and the entrance and friction loss in the pipe must not exceed 2 ft. each, a total of 4 ft., at the maximum rate of 1000 gal./min. and not have so much leakage that regulation is uncertain at 250 gal./min., the minimum rate at which guaranteed accuracy must be maintained (usually within ± 2 or 3%) by the controller. The above is fairly typical of the requirements for such a control valve which, in addition, is often required to move from its wide-open to its most nearly closed controlling position within less than 15 seconds, even for 16" sizes.

The valve thus has a friction factor k' range of 0.125:15.375 or 1:123. The minimum area is

$$A/A_1 = \frac{1}{1+\sqrt{123}} = 0.083 \qquad (25)$$

and the maximum area is

$$A/A_1 = \frac{1}{1+1} = 0.500 \qquad (26)$$

or only about *six* times the minimum.

To regulate accurately, the self-operating controller's valve must be of a thoroughly balanced type as to both kinetic and static pressures. A butterfly valve in a reduced section, although excellent when pilot-operated, tends to be so strongly self-closing when nearly closed as to be impracticable for self-operating controllers. The design should be such as to have the opening closed by a gate-like motion instead of a cam-like sliding action, since the latter may not certainly give the continuous increase of area with opening necessary for the satisfactory operation of a self-operating controller.

In a self-operating controller, the valve opening increases at about the same rate per unit of movement when nearly closed as in any more open position. This is necessary to ensure positive operation of the controller. However, a relay-type controller would have a reduced width of opening near the nearly-closed position, as pointed out in an earlier portion of this chapter.*

*See *Instruments*, March, 1933.

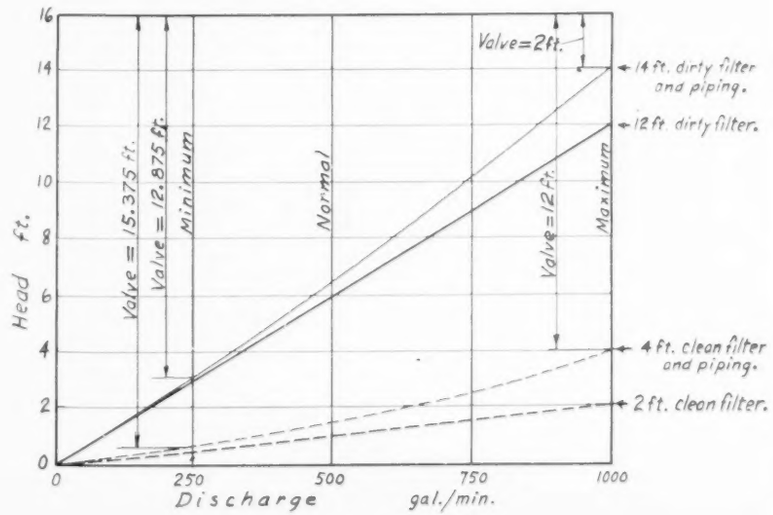


Fig. 28-16. Filter Regulation.

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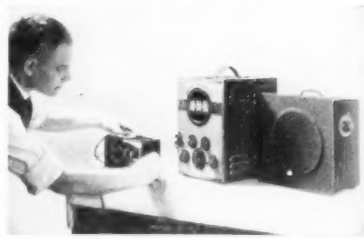

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To operate the control valve, a large thin "flat" diaphragm is often used. This requires accurate compensation for the changes of effective area with valve travel, unless a more expensive molded diaphragm is used. Since diaphragms have relatively small inertia and "storage" they have less tendency to start a hunt than other differential responsive means. Of course, with a flat diaphragm, the position of greatest effective area should correspond with the nearly closed position of the valve, at which position the kinetic "self-closing" effects of the flow are greatest. By careful design and experience, the self-operating controller may be used up to 20" line sizes, up to which size its low maintenance cost, freedom from complications and inherent high stability give this type preference.

The low loss generally required with these devices makes the use of the Venturi tube as the differential producer universal in this field. Metering heads of from 2 ft. to 10 ft. are common. Although competition has recently brought about the lower limit, 6-8 ft. metering heads are still widely accepted as good practice as providing reliable operation with small maintenance.

On the whole, the above four cases illustrate the sort of problems faced by engineers working with automatic flow controllers in various applications and give an idea as to how to solve such problems. It is apparent that the figures given are relative and only as examples of the sort of work necessary for the practical working out of such problems. The figures for loss in the control valve and piping of the boiler feed regulator example are purposely given as lower than usual practice, with the idea that this would show to better advantage the difficulties met with in practice.

Acknowledgment. The following assisted on the article: E. R. Loud, Engineering Dept., Builders Iron Foundry; and C. O. Fairchild and P. F. K. Erghuth, respectively of the Research and Engineering Depts., C. J. Tagliabue Mfg. Co.

ATOMIC STRUCTURE IN RELATION TO HARDNESS

Continued from page 71

may be located in the different corners of a cube. Langmuir also pictures in an atom model the arrangement of the valence negatrons for the sodium and chlorine atoms and indicates how the interatomic electrical forces might function.

Consider once more the various elements as they are arranged in ascending order of atomic number. Fig. 20 shows the hydrogen atom. It consists of one proton as the nucleus and one negatron which is a valence negatron. The atomic number is 1. The negatron is said to be in the K shell. The next in atomic number is helium. It has two negatrons in the K shell and this seems to satisfy the valence conditions, for helium is an inert element: the K shell is complete. Continuing to add successive shells and build up other atoms, Fig. 23(*d*) shows the sodium atom. It has 11 valence negatrons, two in the K shell, eight in the L shell and one in the M shell. It has an atomic number of 11. If the valence negatron in the M shell is taken away, a positive sodium ion remains. On the other hand, the chlorine atom, Fig. 23(*e*), has two negatrons in the K shell, eight in the L shell and seven in the M shell. Its atomic number is 17. The M shell of chlorine is not complete. See Fig. 23(*e*). It readily takes on an extra negatron, completing the M shell, and becomes a negative chlorine ion. The negative chlorine ion and the positive sodium ion unite and form a molecule of common table salt (sodium chloride). When these two ions come together they are held by electrical attractions of the two unlike charges. Whenever two ions, having separate, complete outer shells of eight negatrons each, are held together by electric attraction, it is called in chemistry a "polar bond." Even in those combinations called "non-polar bonds," all shells of eight negatrons must be complete. It is beyond the scope of this work to go farther with this subject. It is desired only to point out the possibility that not only the constituent parts of atoms are held together by electrical and magnetic forces, but also these same forces are a part of the interatomic forces which go to produce the cohesive and adhesive forces of a body and hence its hardness.

To be continued

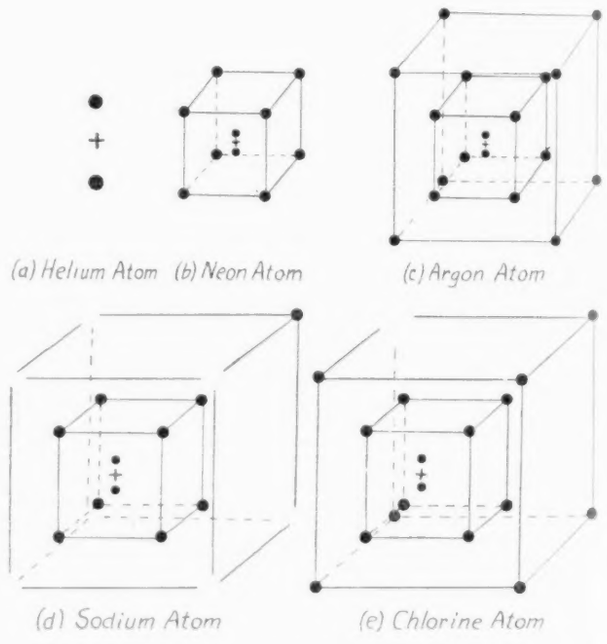

Fig. 23. The positive sign represents the positive nucleus of the atom. The black dots are the valence or extra-nuclear negatrons (— electrons). Upper row: All shells in the atoms are complete and therefore give inert elements. Lower row: The one valence negatron in the M shell of the sodium atom will just complete the M shell in the chlorine atom and when they come together sodium chloride is the result.

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INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

Problem No. 3 Subject Index 8
(January 1937 problem)

"We are doing some experimental work in which we heat a tube to 1800° or 2400° F. while passing oxygen through it. We would like to obtain an apparatus which would allow us to close the tube and measure accurately the rate at which the oxygen (1—1,000 cc.) reacts with the inside of the tube. The increase in temperature inside the tube demands that the apparatus be able to take up the increased pressure."

85 PRIZE DISCUSSION
By H. J. WILMARTH

Re-worded, it is required "to devise a method of measuring the rate at which oxygen reacts with the interior of a completely closed metal bomb."

The crux of the difficulty lies in the requirement that the bomb be closed. Two possible reasons for this requirement suggest themselves:

(*a*) The oxides formed may be volatile, and it is necessary to attain or approach equilibrium of the system metal-oxygen-metal oxide.

(*b*) The point of interest is the rate at which oxygen is lost from the interior of the bomb.

Since at the temperatures mentioned, solution of oxygen in the metal and diffusion of oxygen through the metal may equal or even dominate the chemical combination, these two problems are not equivalent.

Assuming that it is necessary to work with a completely closed bomb, two methods suggest themselves:

(1) The bomb is filled with oxygen to the desired pressure, closed off, and heat-treated on a recorded schedule.

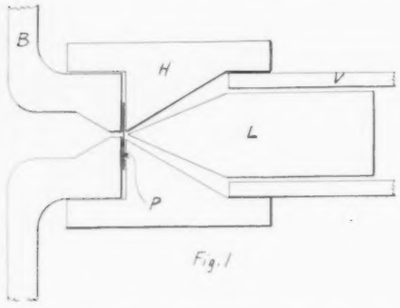


Fig. 1

After cooling, a pressure gage is attached to the bomb through a fitting such as that sketched in Fig. 1. Here *B* is the wall of the bomb, necked out and drilled at the end of the neck with a fine hole (<0.050"), over which the cap *H* clamps a tiny disk of platinum sheet *P*. To make connection to the bomb, the brass tube *V* is fastened to *H*, and the sliding steel punch *L* is driven magnetically against *P*, puncturing it. In this way the gage can be connected to the bomb without losing gas.

By making a large number of these runs with different heat-treating schedules, the loss of oxygen from the interior of the bomb can be worked out as a function of time and temperature.

(2) If a coil carrying a moderately high frequency current is placed around the bomb, the bomb is effectively the short-circuited secondary of an air-core transformer, and precision impedance measurements on the coil will give a continuous record of the removal of metal from the interior of the bomb. Two special conditions must be fulfilled, however: the oxidation of the interior of the bomb must proceed uniformly over the surface, without forming pits or fissures; and the hot resistance of the metal remaining must be constant, that is, there must be no progressive intergranular corrosion in the mass of the metal.

The methods for studying oxygen clean-up at the free surface of a metal are described frequently and at length in the chemical literature (Langmuir's papers on the reaction of hot tungsten with various gases are a good place to start), so it isn't necessary to discuss them here. There remain methods for answering questions (*a*) and (*b*) without going to the time, expense, and technical skill required by methods (1) and (2).

For problem (*a*), I would suggest the apparatus sketched in Fig. 2. A bomb *B*

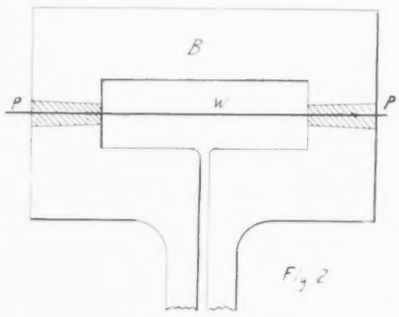


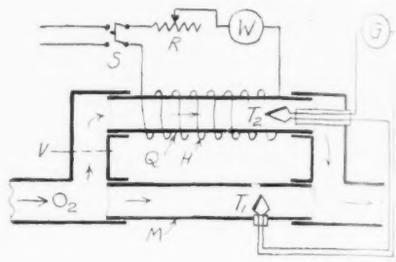
Fig. 2

of the metal studied is connected to a source of oxygen through a side tube, and heated to the required temperature in a neutral atmosphere whose pressure just balances the oxygen pressure inside the bomb. *W* is a wire of the same material, drawn through two close-fitting Steatite or high-temperature porcelain bushings (Stupakoff Labs., Pittsburgh, Pa.) to prevent welding of the wire to the bomb. The wire is drawn along at the required intervals, and a study of the withdrawn wire will reveal the rate and type of reaction.

For problem (*b*), a side tube to an oxygen supply is the obvious solution. If the metal oxidizes too rapidly, then a side tube on Nichrome or even platinum in a small size could be used. The initial investment in platinum is high, but it is more than 90% recoverable.

85 PRIZE SOLUTION
By M. G. JACOBSON

By means of two elbows a second (for comparison or reference) tube is connected in parallel with the main tube *M* in which the oxygen reaction takes place. This second tube *Q* is made of fused quartz, alumina, silica or another material saturated with oxygen and therefore not attacked by it. Around tube *Q* is wound electrical heater wire *H* which is connected to supply through



rheostat *R* and wattmeter *W*. Valve *V* permits controlling the gas flow through this second tube. Thermocouples T_1 and T_2 are installed in the two tubes respectively and connected electrically in opposition through a galvanometer or millivoltmeter *G*.

Before making the tests with O_2, nitrogen or another inert gas is passed through the tubes at approximately the same rate of flow at which the oxygen is used. Both tubes are placed in the same oven which is used to heat the oxygen tube and heated to the desired temperature. Then, with the inert gas flowing, valve *V* is adjusted until galvanometer *G* shows zero, thus indicating that both tubes are heated to the same temperature.

Now the inert gas is replaced by oxygen. As soon as the reaction with the walls of tube *M* begins, galvanometer *G* will show a deflection. Switch *S* is closed and rheostat *R* is adjusted until galvanometer *G* is back to zero. The indication of wattmeter *W* then is proportional to the rate of consumption of oxygen by tube *M*.

From time to time, as the oxidation of the walls of tube *M* progresses to such extent as to materially change its diameter and surface, valve *V* will have to be reset with an inert gas going through the apparatus.

Wattmeter *W* can be replaced by an ammeter in series and a voltmeter in parallel with coil *H*.

Obviously, with this method it is not necessary to close the tube, although this can be done if desired.

Problem No. 5 Subject Index 2.02

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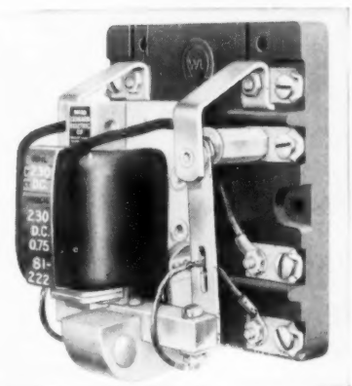

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E55 **Feedwater De-aerators.** 16-page 8½" × 11" Publication 2540, entitled "Preventing Corrosion by 'Zero Oxygen'," presents a technical discussion and describes new equipment. Cochrane Corp., 17th St. Allegheny Ave., Philadephia, Pa.

E56 **Industrial Motion-picture Outfit.** 12-page 6" × 9" booklet, also six 8½" × 11" sheets, descriptive of industrial motion-picture camera, closed-loop projector and accessories for motion study and other engineering purposes, and narrative of some results obtained. Production Control Machines Corp., Chrysler Bldg., New York City.

E57 **Current Meters.** Latest issue of 1-page "Current Meter Notes" discusses relation between dow force and meter action. Scientific Instrument Co., 1441 Walnut St., Berkeley, Calif.

E58 **Timers.** 8-page 9" × 12" catalog illustrates and describes large number and variety of pocket, wrist and lapel stop watches, timers, chronographs, etc., made by Gallet, Guinand, Galco and Jarco. M. . Stillman Co., Inc., 116 South Michigan Ave., Chicago, Ill

E59 **Insulation Tester.** 6-page 8½" × 11" Catalog No. 11, Section 2, describes "Hipot" Insulation Tester which permits the testing of individual porcelain insulators on live lines. Roller-Smith Co., 233 Broadway, New York, N. Y.

E60 **Metallographic Equipment.** 4-page 8½" × 11" Bulletin E-240 (and 1-page price list) describes and gives specifications of research metallographic equipment for visual and photographic work. Bausch & Lomb Optical Co., Rochester, N. Y.

E61 **Relays.** 4-page 8½" × 11" descriptive announcement of "Series 110" for a.c. and "Series 115" for d.c. Guardian Electric Mfg. Co., 1621-27 West Walnut St., Chicago, Ill.

E62 **Triple-control Hardening.** Envelope-size folder describes Hump-Vapocarb Method of hardening jewelry dies. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

E63 **Photoelectric Cells.** 16-page 8" × 10½" technical booklet on the G-E Light-sensitive Cell contains thorough discussions and numerous diagrams of characteristics. General Electric Co., Schenectady, N. Y.

E64 **Electrical Instruments.** 4-page 8½" × 11" Form RM-3 entitled "Hoyt Meters for Radio Amateurs and Radio Service Men." Burton-Rogers Co., 755 Boylston St., Boston, Mass.

E65 **"The General Radio Experimenter."** The January 1937 issue of this 8-page 6" × 9" house-organ contains a full-length article on the measurement of mutual inductance, also items on new wave filters, voltage divider, wide-range r-f choke, and miscellaneous items. General Radio Co., 30 State St., Cambridge A, Mass.

E66 **Oscillographs.** 8-page 5¾" × 8¼" Booklet SH-6235 describes Siemens portable electromagnetic type oscillographs. Also a 6-page folder on the Siemens & Halske oscilloscope. Siemens & Halske AG, Wernerwerk, Berlin-Siemensstadt, Germany. Herman H. Sticht & Co., Agents, 27 Park Pl., New York, N. Y.

E67 **Flow Meter.** 16-page 7¾" × 10½" Catalog N-28 describes "Centrimax" metering equipment employing radically new principle whereby differential is balanced against centrifugal force following the same square-root relation. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

E68 **"The Laboratory."** Vol. 8, No. 4 of this 16-page 6" × 9" house-organ contains a full-length historical article on Henry Cavendish; also a technical article on Polaroid; also miscellaneous announcements. Fisher Scientific Co., 711-723 Forbes St., Pittsburgh, Pa.

E69 **Watthour Meters.** 6-page 8½" × 11" Catalog Section 42-104 describes Type OB switchboard watthour meters of the single-phase, 3-element types; includes applications, performance characteristics, wiring diagrams and ratings. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

E70 **Polyphase Meters.** 16-page 8½" × 11" Catalog Section 42-210 describes polyphase detachable meters and application, gives wiring diagrams and performance characteristics. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

E71 **Potentiometer Recorder.** This is not so much a piece of literature as a cardboard "model" (technically known as a "die-out") of the new Micromax recorder. Its effect is almost to put a half-size model in your hands: you open the door of the case, then swing out the chart carriage and finally swing the whole mechanism into view. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

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